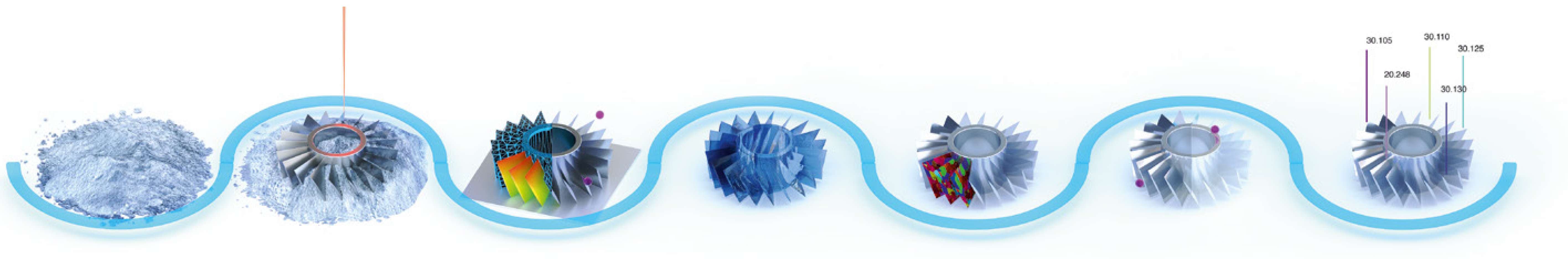
Additive Manufacturing

Improving Yield with Holistic Quality Inspection and Correlation


From Powder to Performance.
ZEISS 3D ManuFACT
// INNOVATION
MADE BY ZEISS

ZEISS 3D Manu**FACT**
The Holistic Integrated Process for Additive Manufacturing



Powder and Material Characterization

SEM, LM, X-ray CT

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In-Process Metrology and Data Analysis

Post-Print Heat Treatment and Part Removal

CMM, 3D Scanning

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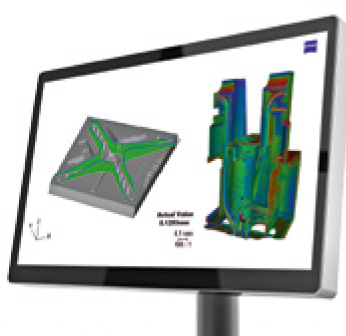

Defect and Inner Structure Inspection

X-ray CT, LM

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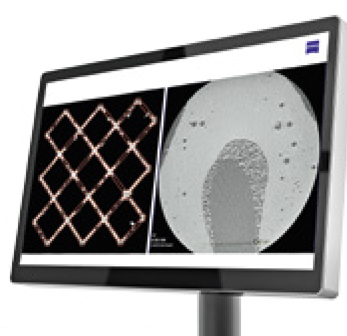

Post-Print Material Quality Inspection

SEM, LM, X-ray CT

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Dimensional and Surface Quality Inspection

CMM, X-ray CT, 3D Scanning, LM

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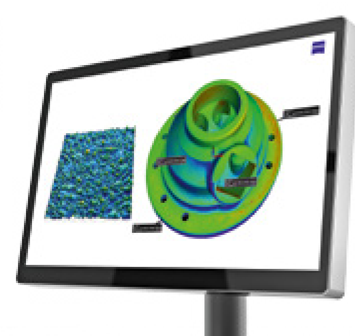

Process Data Statistics and Analytics

PiWeb, Analytics and Correlation Tools

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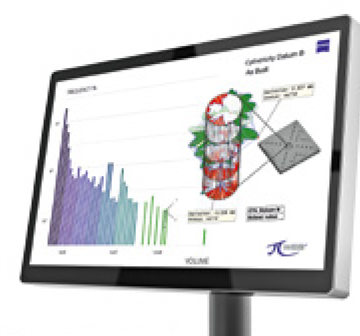
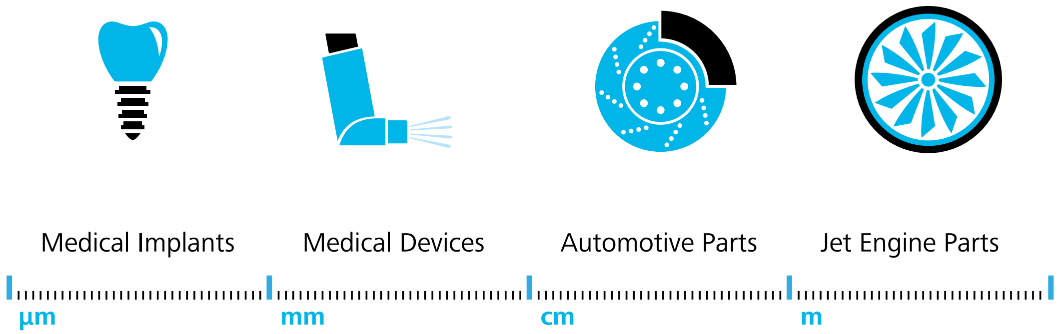


Improving Yield in Additive Manufacturing

3D printing processes – additive manufacturing – are becoming increasingly a part of the industrial production chain. Medical technology, aerospace, and automotive industries are leading the innovation and implementation of additive manufacturing.



ZEISS 3D Manu**FACT** features a selection of products from the ZEISS portfolio. This unique holistic inspection solution for additive manufacturing focuses on:

- MATERIAL COMPOSITION ANALYSIS
- POWDER ANALYSIS
- POST-BUILD ANALYSIS INCLUDING HEAT TREATMENT, PART REMOVAL, AND CLEANING
- METALLOGRAPHIC ANALYSIS
- DEFECT ANALYSIS
- SURFACE METROLOGY – EXTERNAL AND INTERNAL
- DIMENSIONAL METROLOGY – EXTERNAL AND INTERNAL

This integrated process brings the most reliable knowledge and, thus, certainty about the reliability of 3D printed parts.

Powder and Material Characterization

Light Microscope (LM)

Scanning Electron Microscope (SEM)

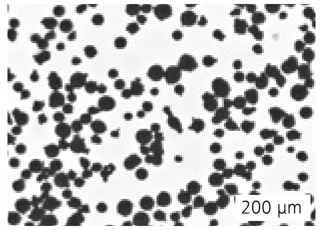
X-ray Computed Tomography (X-ray CT)

Powder is the building block of additively manufactured parts. Size distribution of individual powder particles influences how the powder is compacted and affects the density of the build and the possibility of defects visible later in the process. LM, SEM and X-ray CT help to define the powder quality.

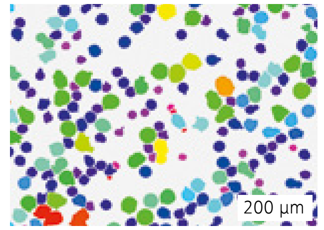
Powder and Material Characterization

Light Microscope (LM)

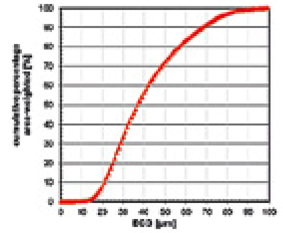
Optical microscopes offer the possibility of quick powder sampling and reliable analysis of particle size distribution.



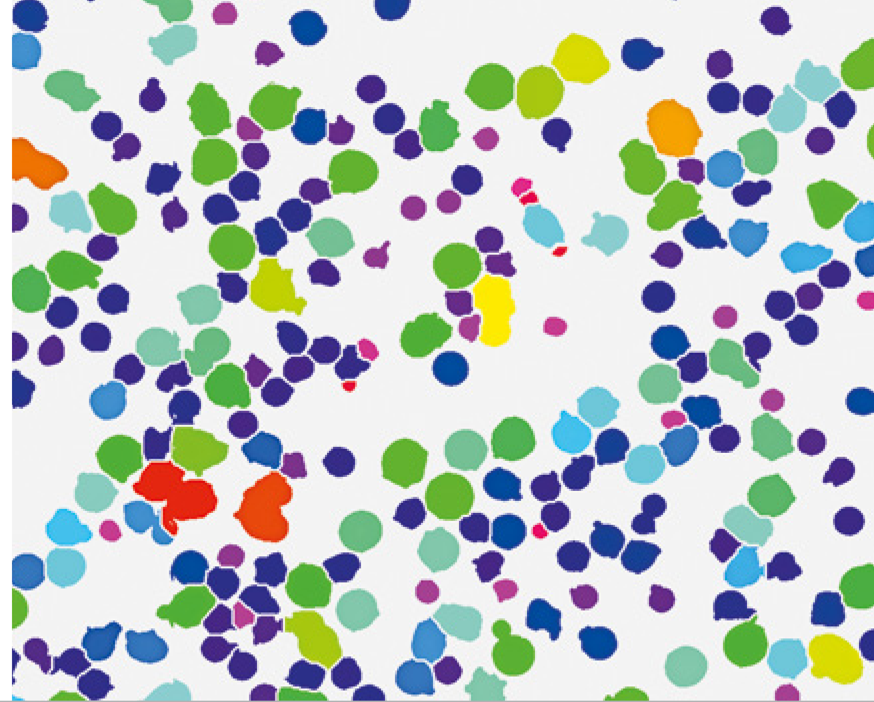
Light microscopy image of metal powder



Automated segmentation

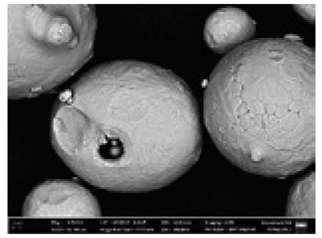


Particle size distribution

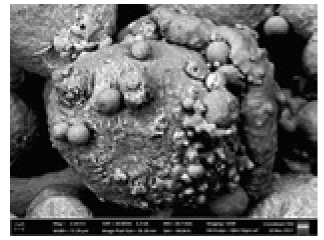


Scanning Electron Microscope (SEM)

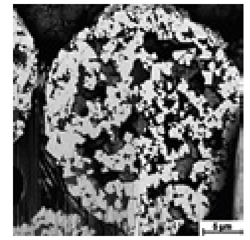
Powder particles are fairly small in size, typically ranging from few micrometers to tens of microns in diameter. Scanning Electron Microscopes (SEM) offer nanometer level resolution and the ability to examine batch or each individual particle to help engineers better understand the build ingredients for additive manufacturing.



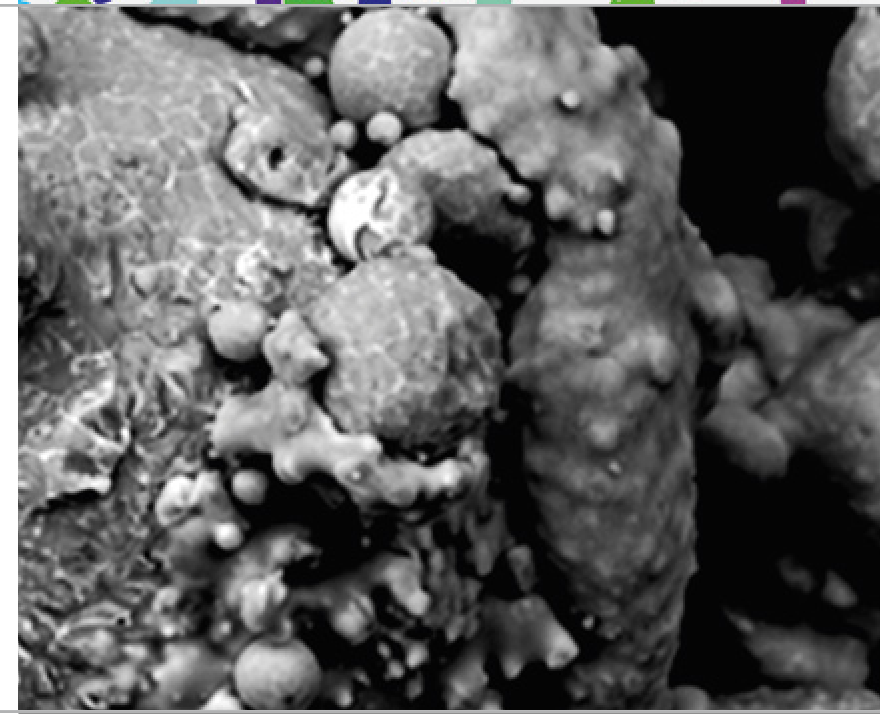
New powder



Recycled powder



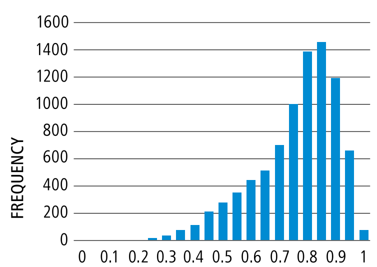
Powder with porosity



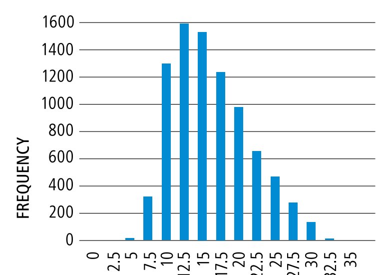
X-ray Computed Tomography (X-ray CT)

High-resolution X-ray CT will allow detailed analysis of particle shape, size, and volume distribution. The analysis of shape in relation to powder bed compactness helps to determine proper process parameters and to shorten optimal print recipe development.

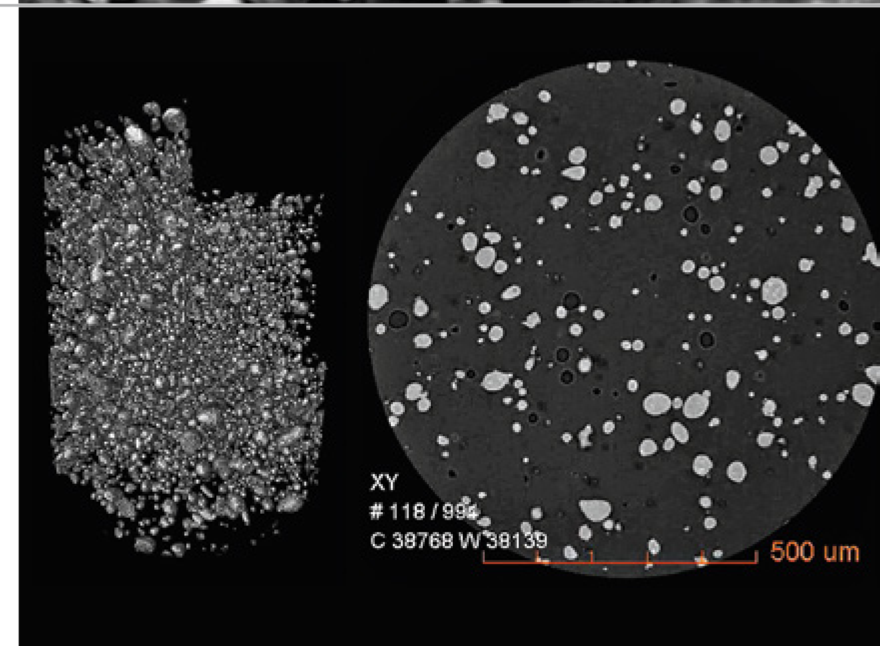
Aspect ratio



Particle diameter

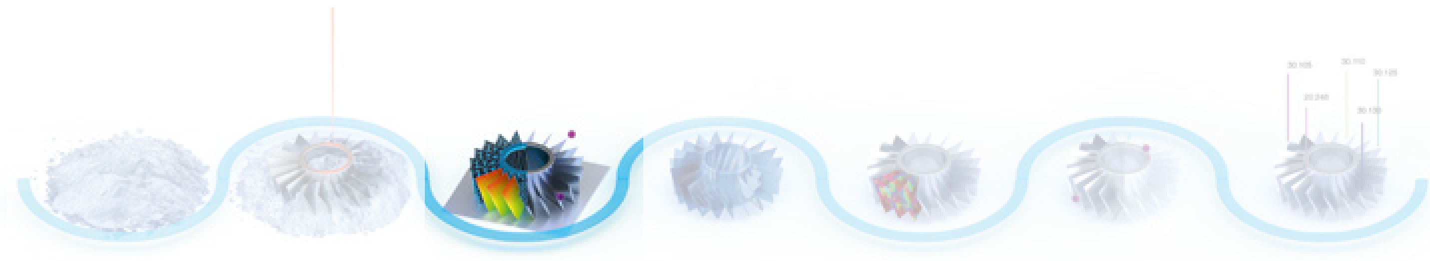


8500+ particles analyzed for aspect ratio and diameter

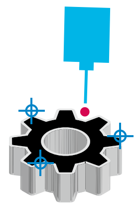


> Imaging of additive manufacturing powder X-ray CT

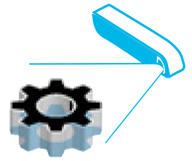
Post-Print Heat Treatment and Part Removal



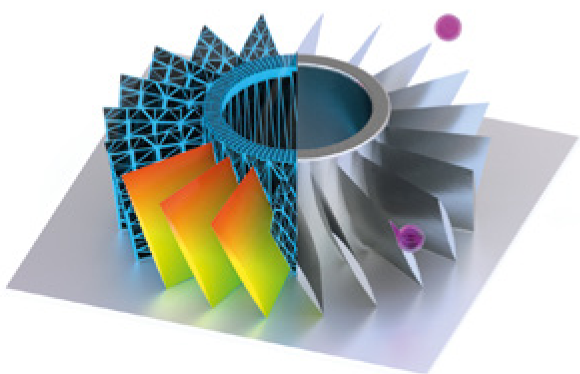
Successful build requires various post-processing treatments to ensure dimensional accuracy and optimal material properties. After printing, the part is still attached to the build plate. It is then heat-treated and removed with wire EDM. To better understand the influence of those processes on final quality, a CMM or optical 3D scanner can be used.

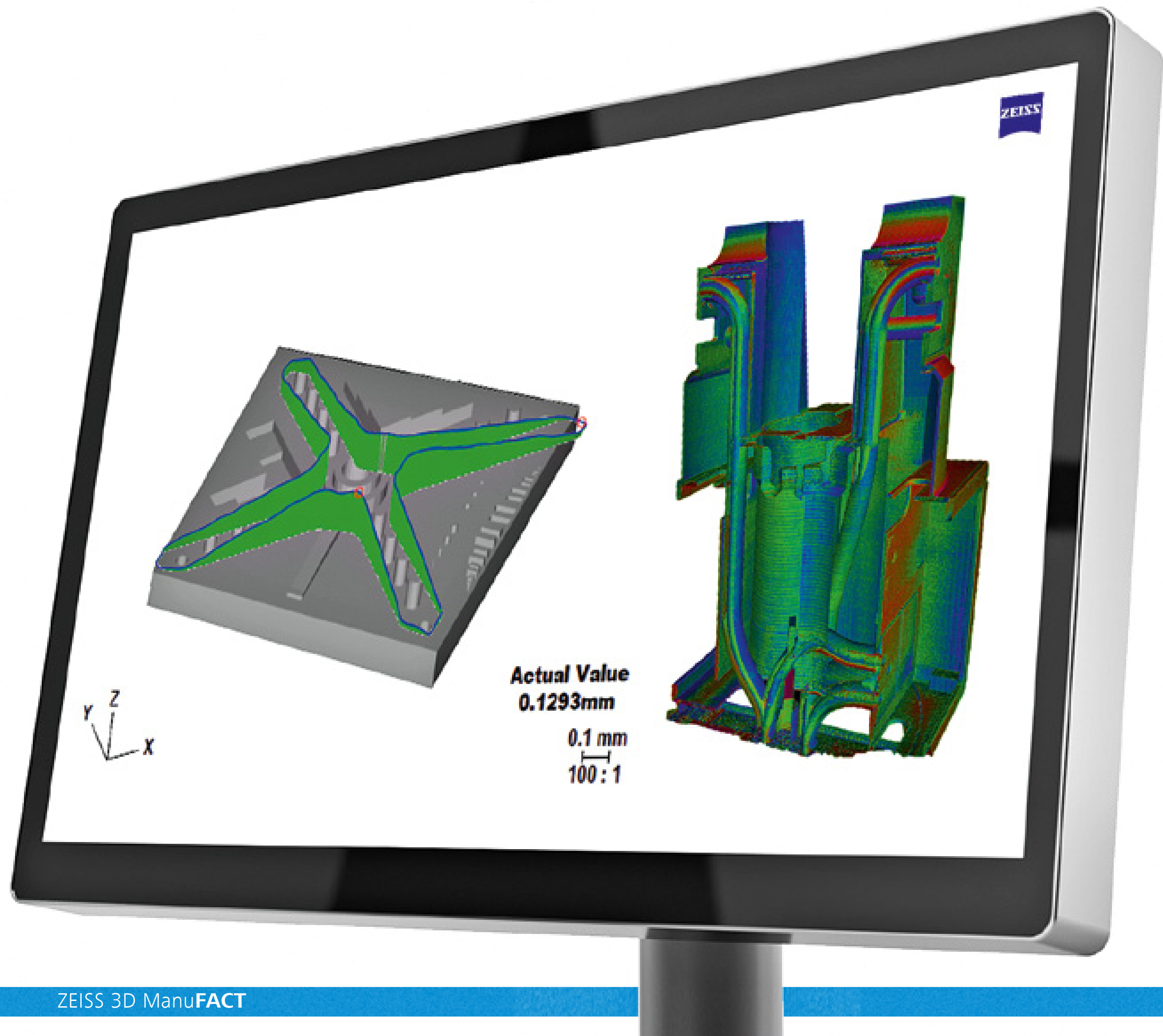


Coordinate Measuring Machine (CMM)

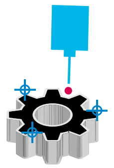


3D Scanning



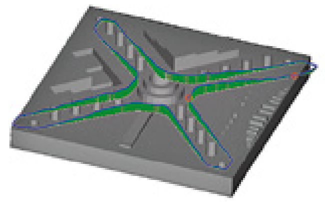


Post-Print Heat Treatment and Part Removal

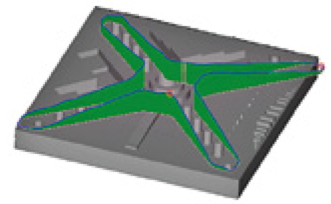


Coordinate Measuring Machine (CMM)

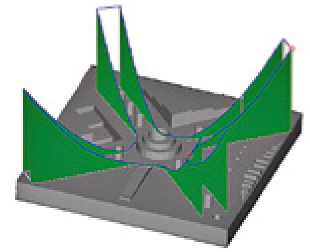
Shop floor CMMs can be used as a quick check of the part's dimensional condition across all three post-process steps: as built, heat-treated, removed and cleaned. Tactile measuring machines allow consistent measurement across many surface finish conditions and metrology of deeper holes and cavities, providing valuable information regardless of part density or finish.



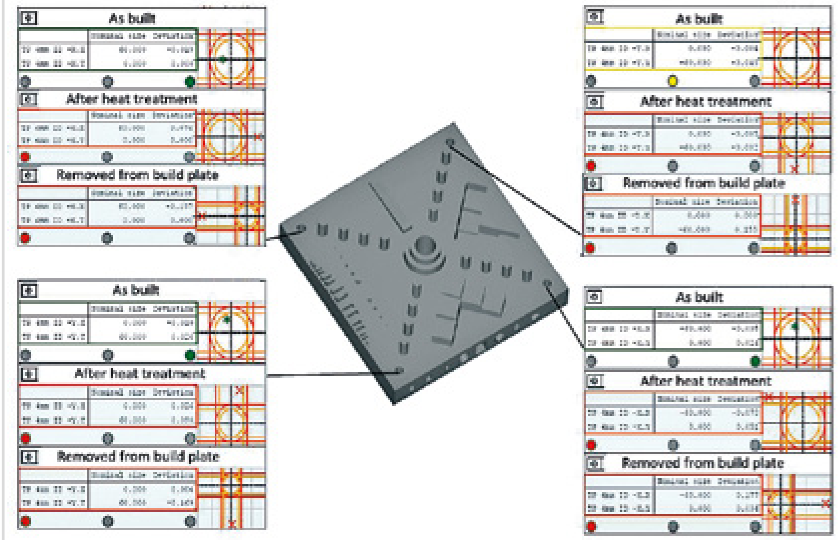
As built

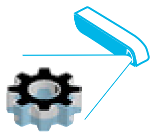


After heat treatment



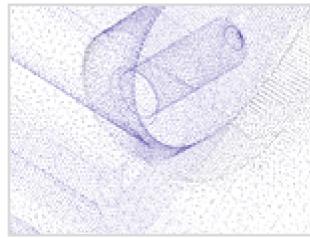
Removed from build plate and cleaned



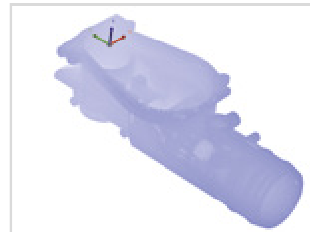


3D Scanning

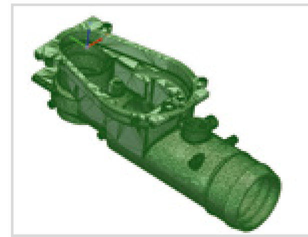
3D scanning offers the ability for high-speed, high density data collection. It can capture data of the entire external surface by generating high density data, allowing to analyze form, size, and location of features as well as the whole part.



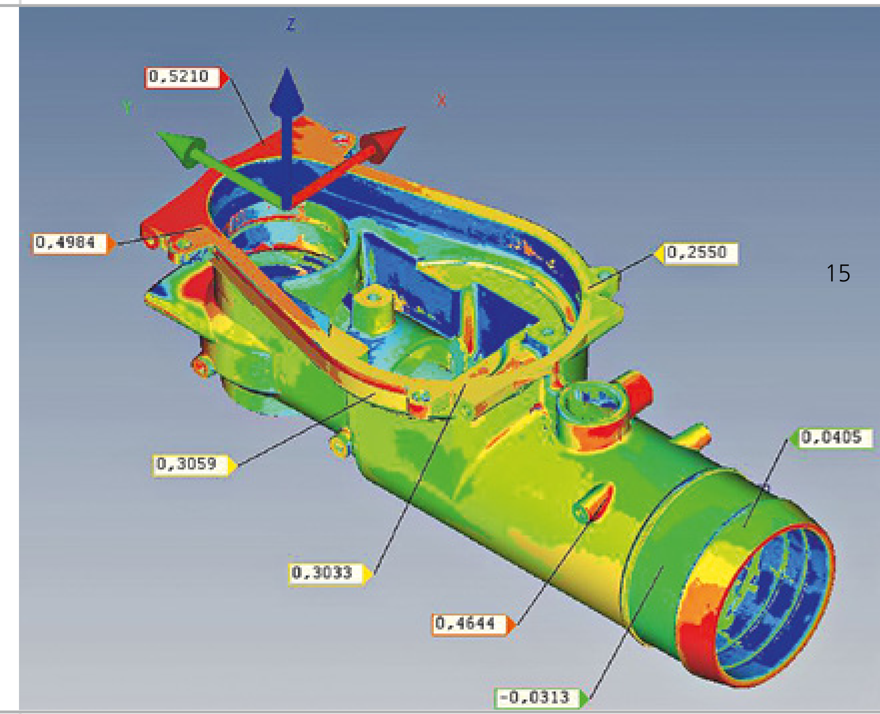
Single point cloud generated with 3D scanner



Combined point cloud of all captured data

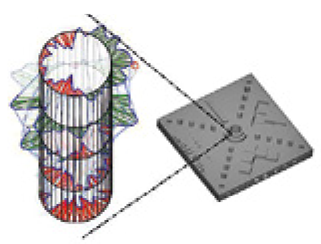


Triangle mesh (STL) calculated on the basis of the captured point cloud



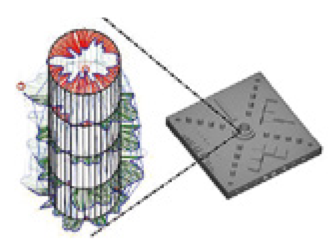
Heat Treatment Effects

The form, size, and position of holes and features can be drastically affected by thermal stresses. The part could be within tolerance in as-built state. However, following heat treatment and part removal, significant distortions may occur.



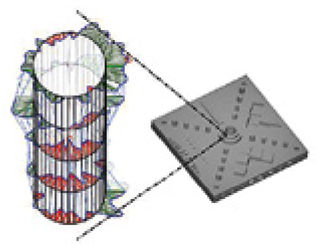
Actual value 0.0531 mm

As built



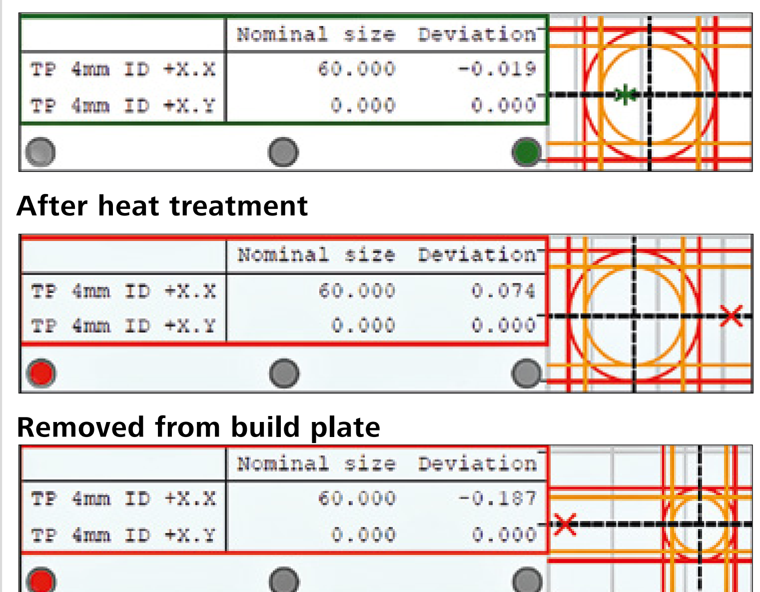
Actual value 0.0457 mm

After heat treatment



Actual value 0.0387 mm

Removed from build plate and cleaned



As built

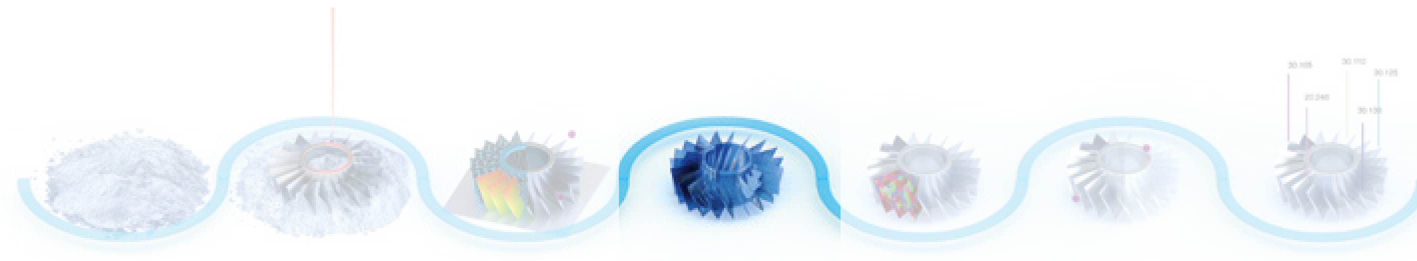
	Nominal size	Deviation
TP 4mm ID +X.X	60.000	-0.019
TP 4mm ID +X.Y	0.000	0.000

After heat treatment

	Nominal size	Deviation
TP 4mm ID +X.X	60.000	0.074
TP 4mm ID +X.Y	0.000	0.000

Removed from build plate

	Nominal size	Deviation
TP 4mm ID +X.X	60.000	-0.187
TP 4mm ID +X.Y	0.000	0.000

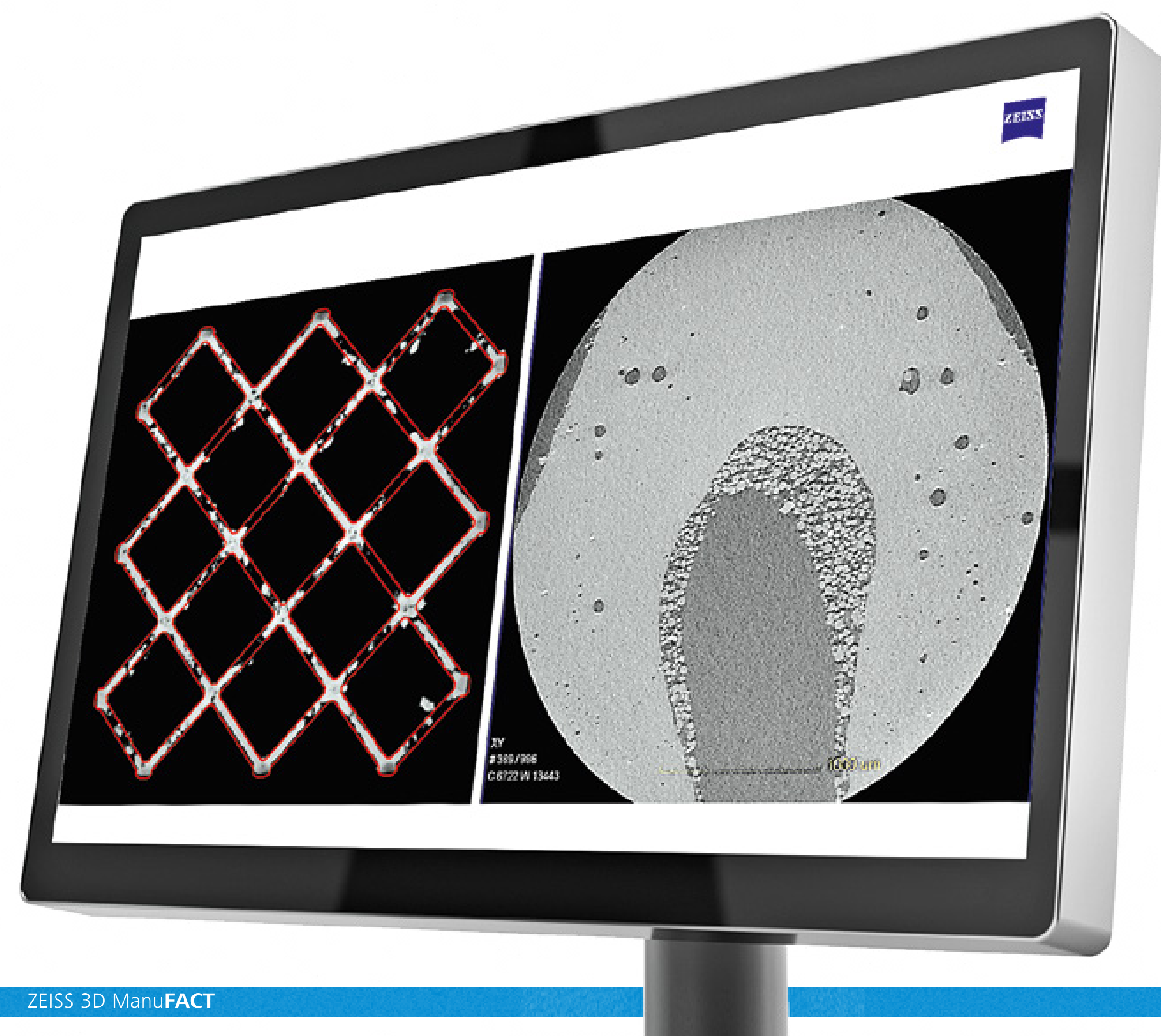


Defect and Inner Structure Inspection

The quality of powder and how it is spread during the build process might cause voids or material impurity to form in the structure. Inspecting the quality of the build with LM or internal structures with high-resolution X-ray CT helps to determine process parameters influence and faster define a possible path to achieve optimal settings.

Light Microscope (LM)

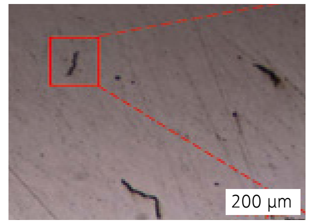
X-ray Computed Tomography (X-ray CT)



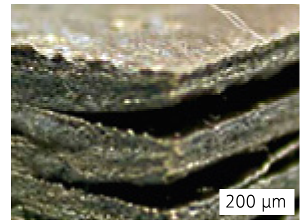
Defect and Inner Structure Inspection

Light Microscope (LM)

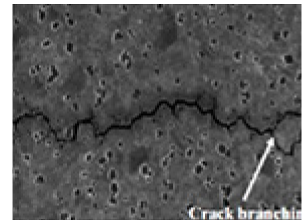
With the use of an optical microscope, a close-up view on the build surfaces and features provides valuable insight into the quality of the part and possible flaws with the process parameters, allowing better understanding of origination of micro cracks and delaminations.



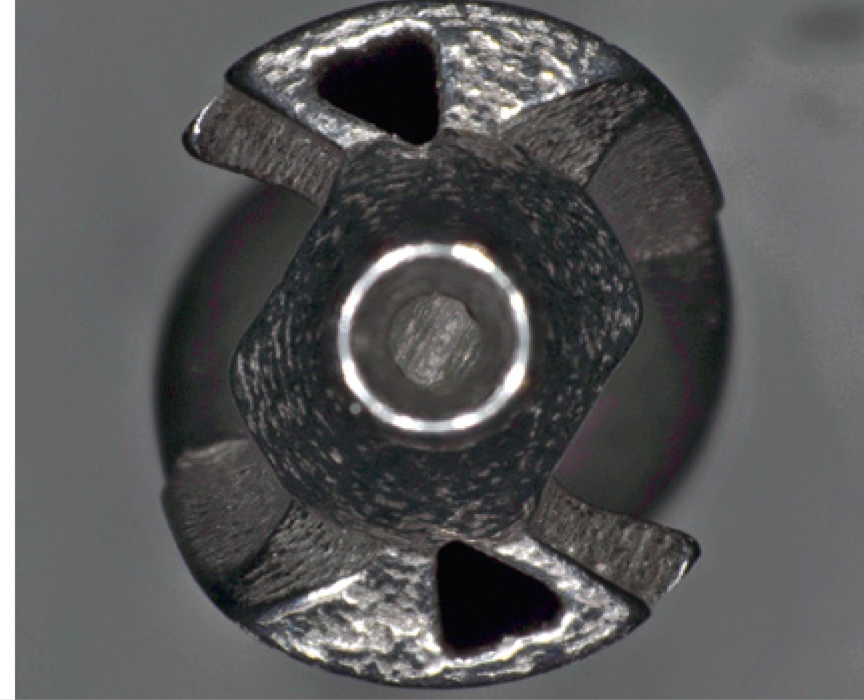
Micro cracks



Delamination

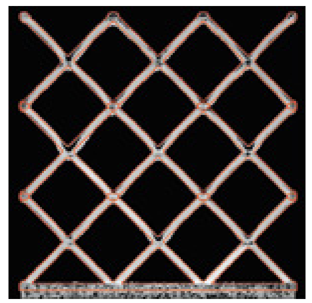


Fatigue cracks

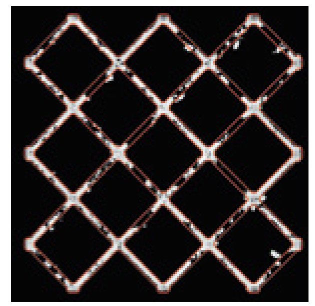


X-ray Computed Tomography (X-ray CT)

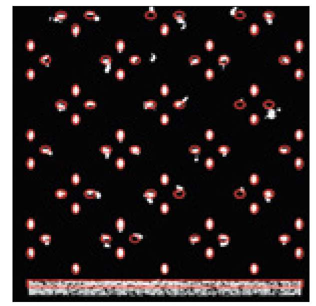
Additive manufacturing opens the door for unprecedented design freedom and allows complex inner structures. High resolution X-ray CT enables unique views of those structures and analysis of potential build defects.



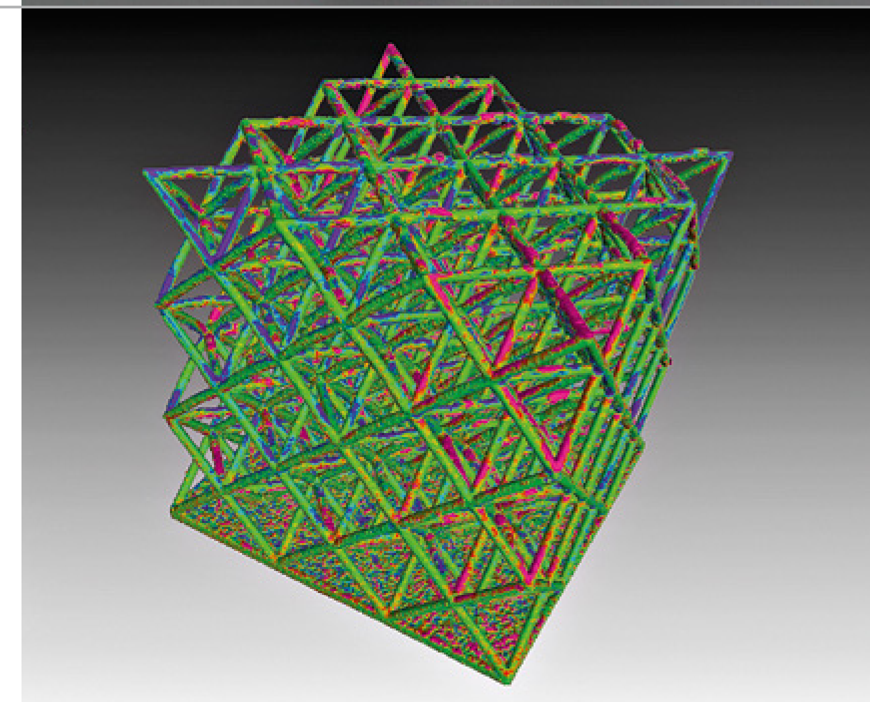
Cross-sectional side view



Cross-sectional top view

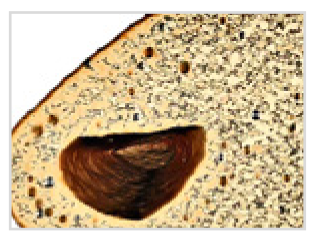


Node view

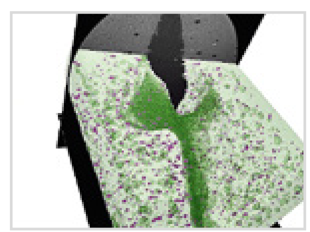


Inner Defects

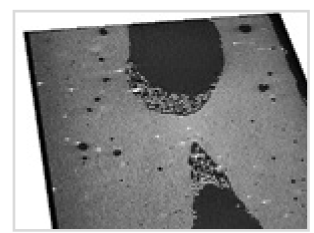
X-ray CT inspection and metrology can provide a unique view of completeness of the build and significantly aid the optimization of the 3D printing process. Scanned images of the part can be cross-sectioned in any direction and compared to the nominal CAD representation.



19 µm voxel resolution imaging is used to see features and porosity



Detection of unmelted particles, high-Z inclusions, and small voids



3.0 µm voxel resolution imaging is used to see fine details

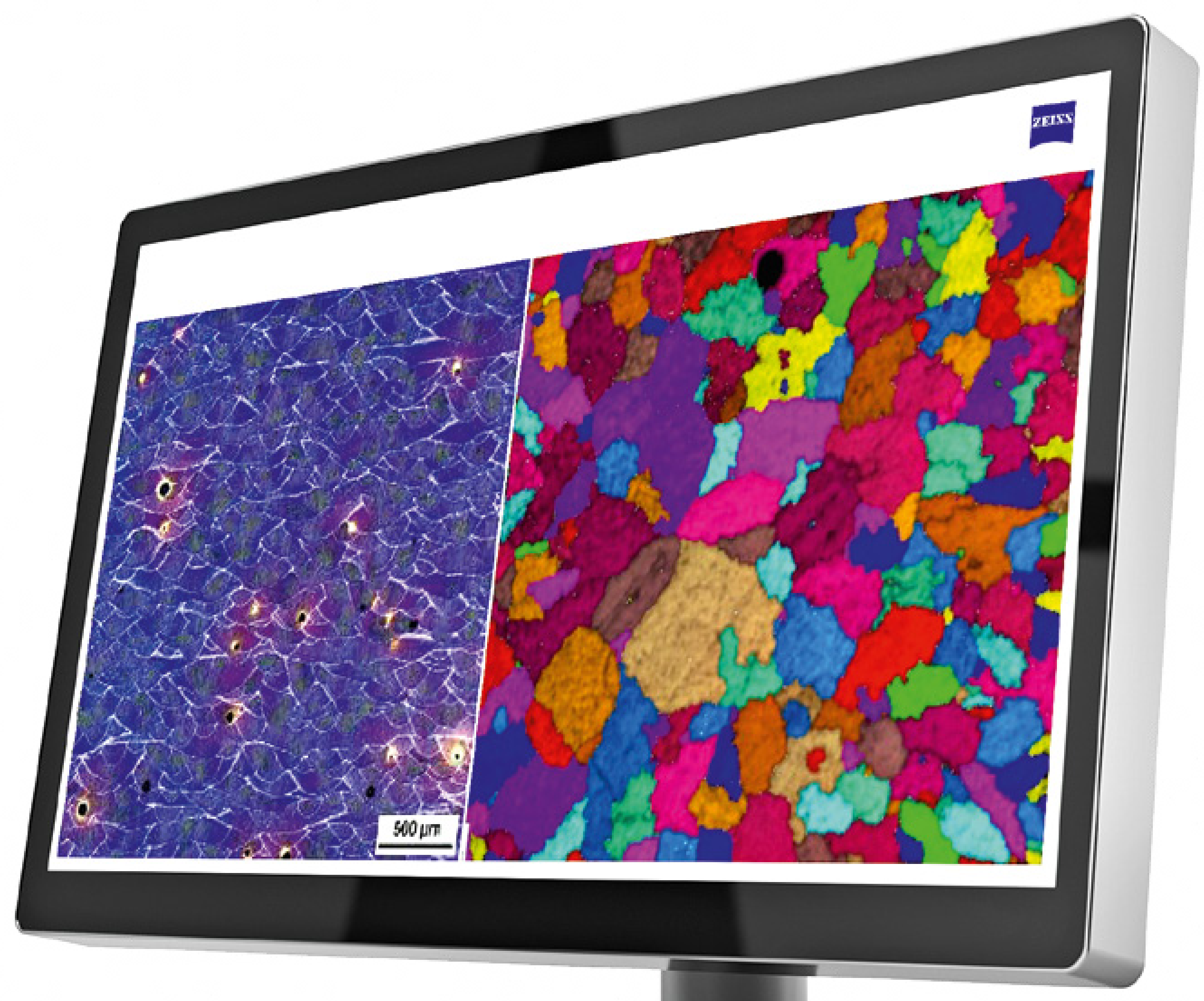
Post-Print Material Quality Inspection

Light Microscope (LM)

Scanning Electron Microscope (SEM)

X-ray Computed Tomography (X-ray CT)

The additive manufacturing process, unlike classic manufacturing methods, requires powders to be melted during the build. Melt temperatures and process parameters greatly affect the crystallographic composition and, as a consequence, part properties.



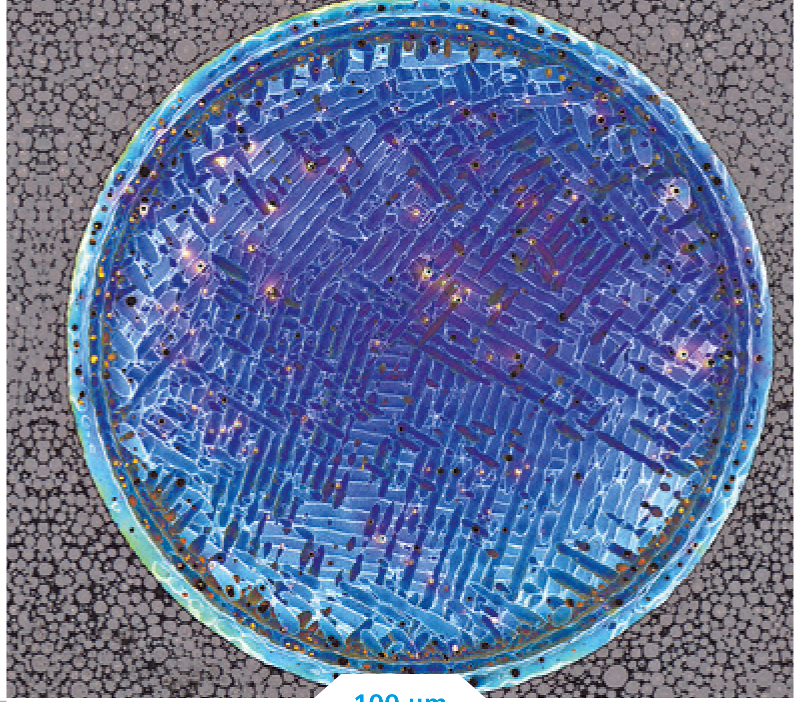
Post-Print Material Quality Inspection

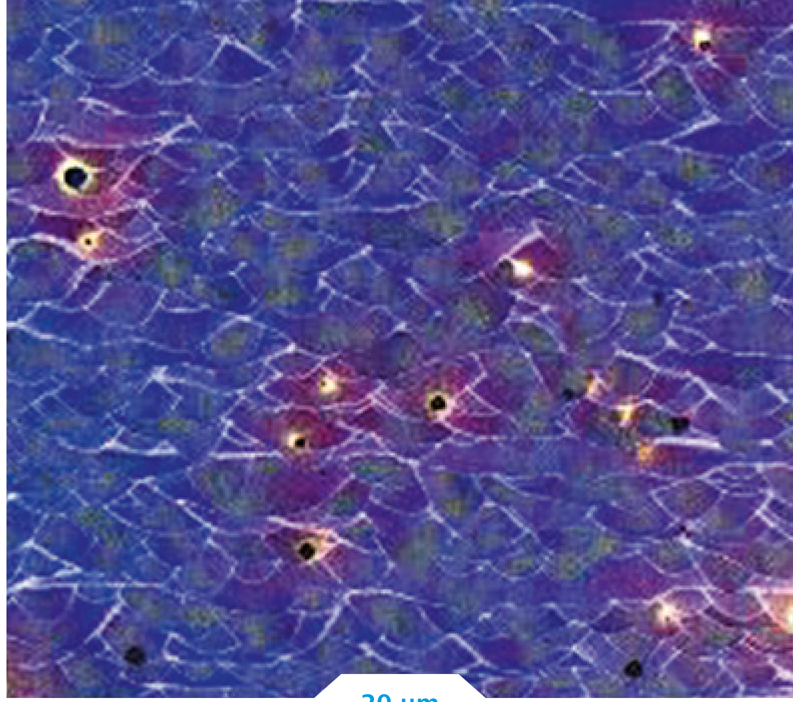
Light Microscope (LM)

Due to heat cumulation, additively manifactured parts are typically created with short localized laser blasts, creating characteristic patterns which can be analyzed with optical microscopes.

\>
Light microscopy
image of metal powder

AlSi10Mg cross section transverse and along the build direction



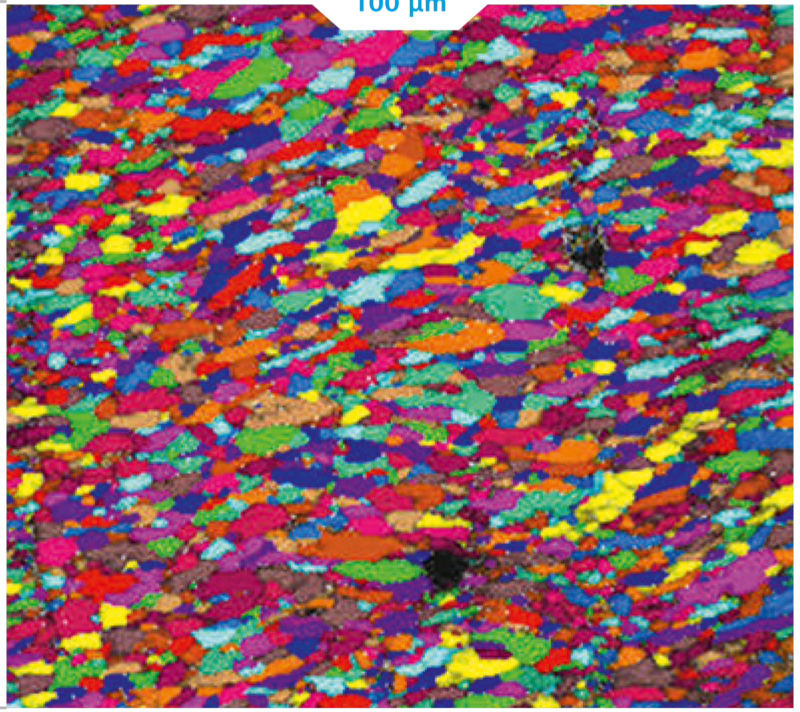


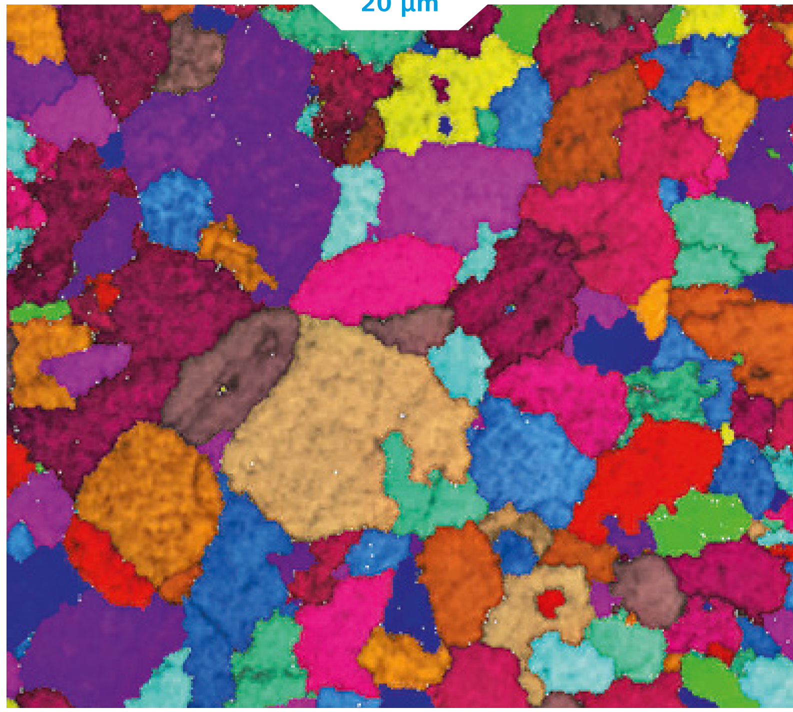
Scanning Electron Microscope (SEM)

SEM with Electron Backscatter Diffraction (EBSD) enable micro-structural-crystallographic characterization and study of crystalline or polycrystalline materials.

\>
Same area
SEM, EBSD

EBSD-mapping, individual grains colored, laser structure not visible



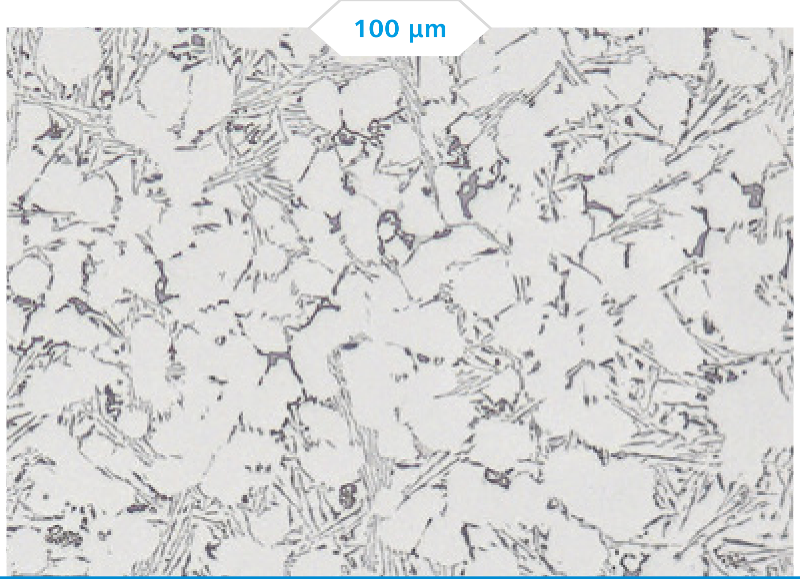


Analysis of Grain Structure

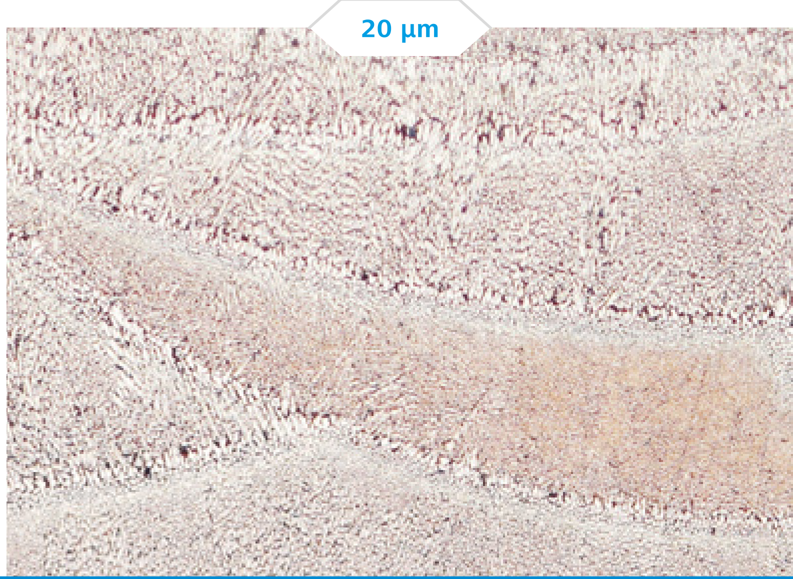
The same material can resemble completely different cristallographic structures for conventionally produced raw stock and an additively made part. Such a difference will drastically influence mechanical properties of the finished part.

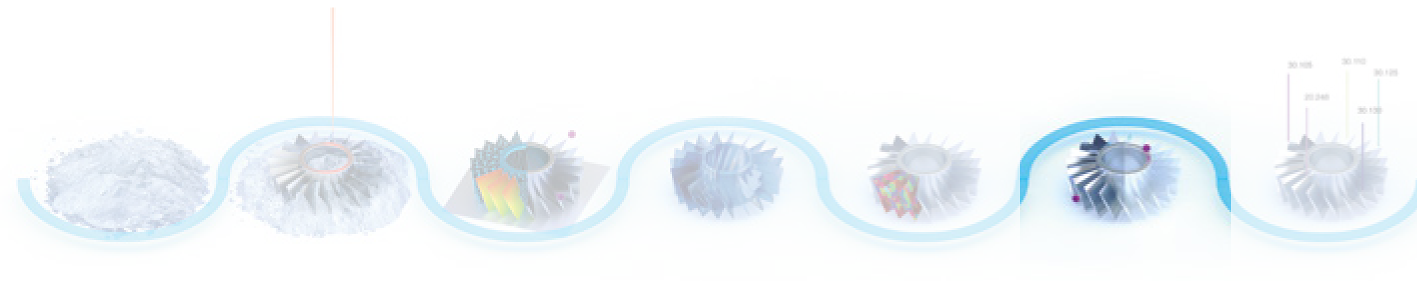
\>
Comparison
of conventional
and additively made
AlSi10Mg

CONVENTIONAL



3D PRINTED





Dimensional and Surface Quality Inspection

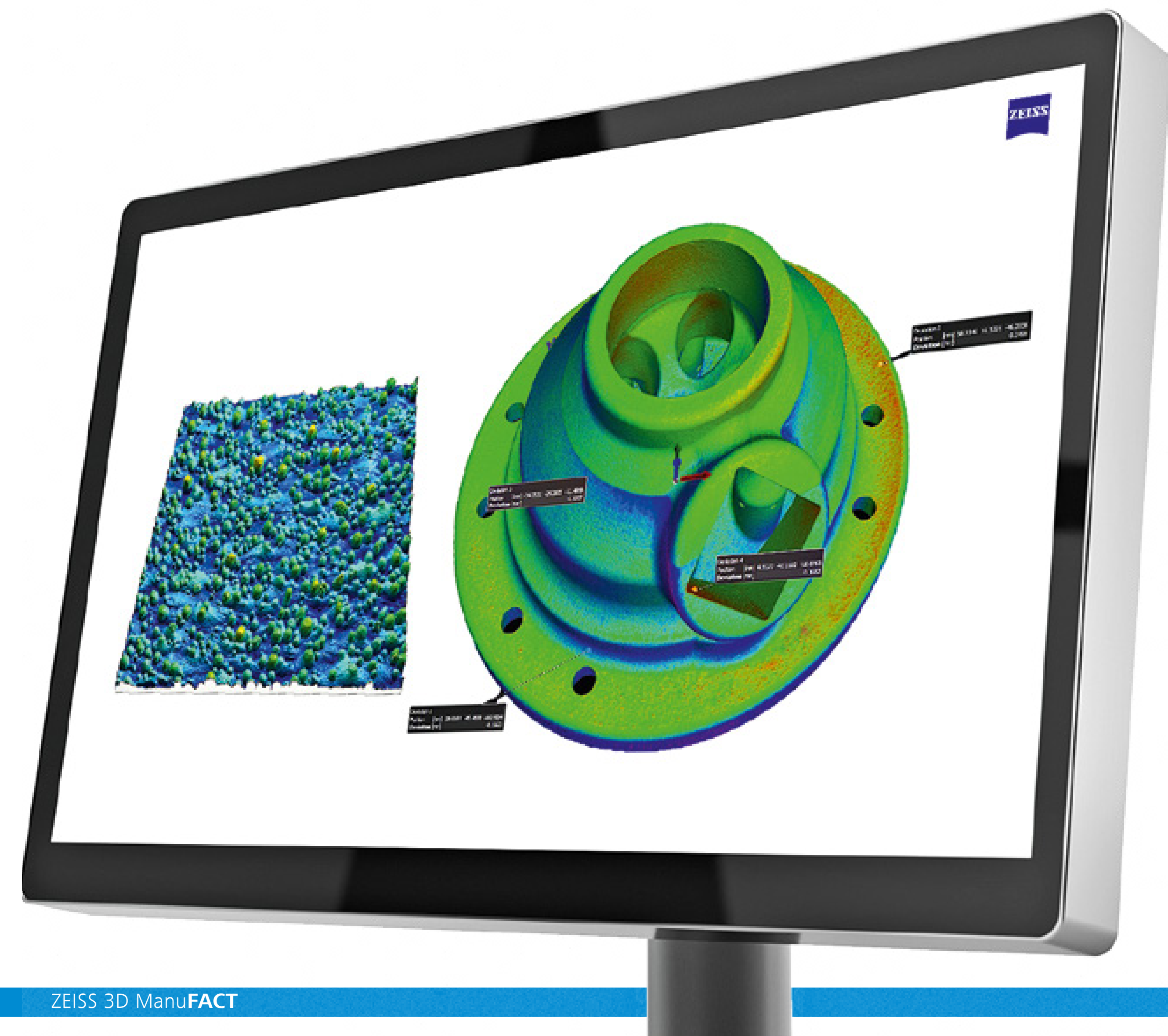
Light Microscope (LM)

Coordinate Measuring Machine (CMM)

X-ray Computed Tomography (X-ray CT)

3D Scanning

Dimensional accuracy and surface finish are critical to ensure proper assembly and consistent mating across multiple parts. The surface finish can be analyzed with optical methods, and the internal surface is examined with X-ray CT. Dimensional accuracy of the final part can be validated either with CMM, optical 3D Scanning or with X-ray CT.

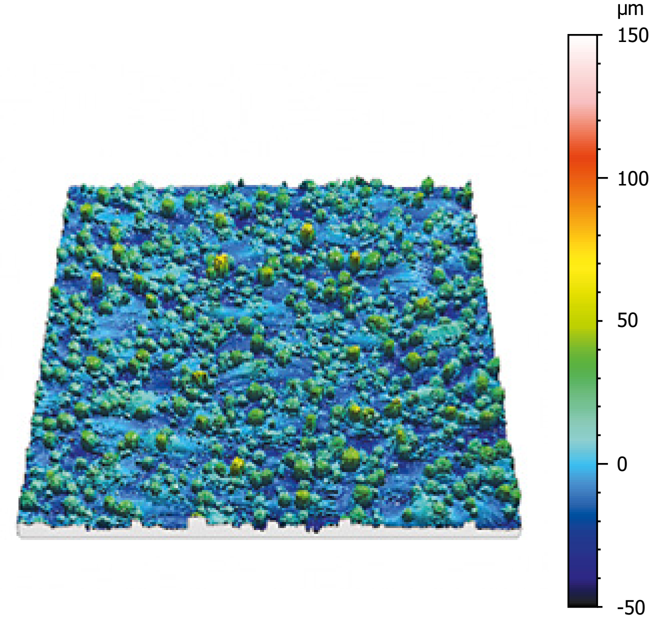


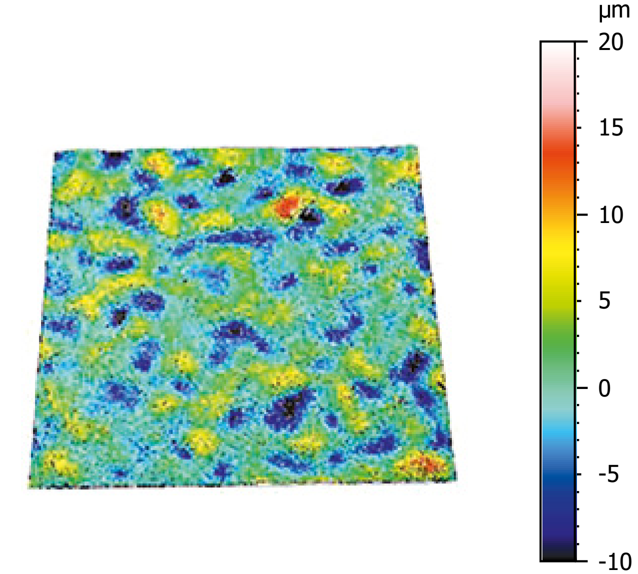
Surface Quality Inspection

Light Microscope (LM)

Surface quality defines functional and visual quality of the part. Optical profilometers offer high density of data in relatively short time, allowing detailed topographic maps of a surface of interest.

>
Analysis of as built part with LM before and after sand blasting





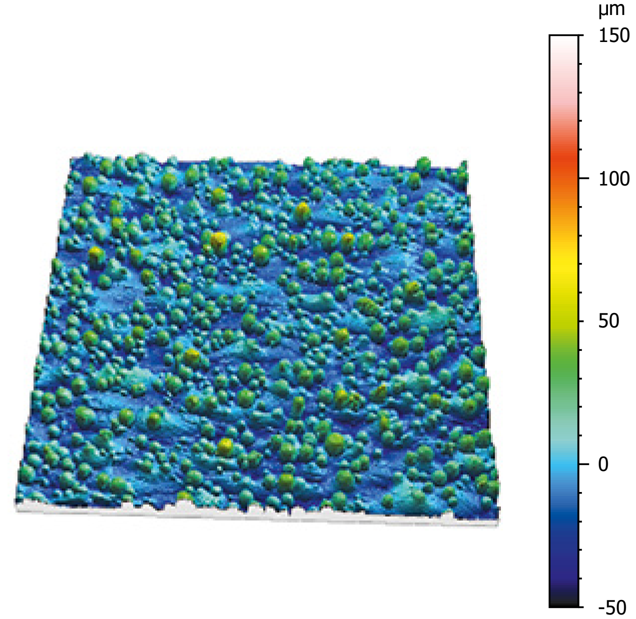
As built

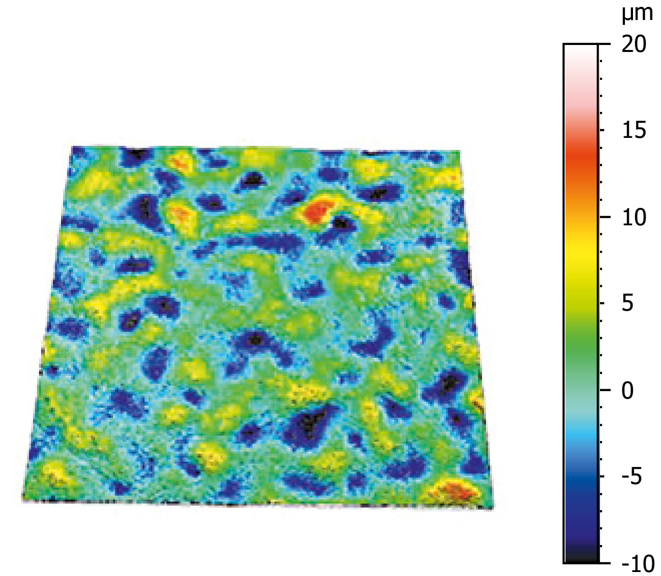
After sand blasting

X-ray Computed Tomography (X-ray CT)

Additive manufacturing allows creation of very complex internal surfaces which often might serve as channels, allowing gas or liquid flows. Internal surface finish can not be accessed with an optical profiler. Therefore, high resolution X-ray CT is the only way to obtain internal surface analysis.

>
Analysis of as built part with high-resolution X-ray CT before and after sand blasting





Surface Quality

Surface roughness is critical with respect to mechanical and visual qualities of the part. Additively manufactured parts can be very complex with hidden inner structures which are not accessible. The ability to use a well-correlated optical profiler and high-resolution X-ray CT enables detailed surface analysis regardless of its location (inner or external).

>
Comparison of surface analysis results obtained with LM and X-ray CT

ISO 25178
Height Parameters

	ZEISS Xradia Versa	ZEISS Smartproof 5	
Sq	15.1	14.8	µm
Ssk	0.700	0.776	
Sku	3.11	3.29	µm
Sp	66.9	71.3	µm
Sv	40.7	86.9	µm
Sz	108	158	µm
Sa	12.2	12.0	µm

ISO 25178
Height Parameters

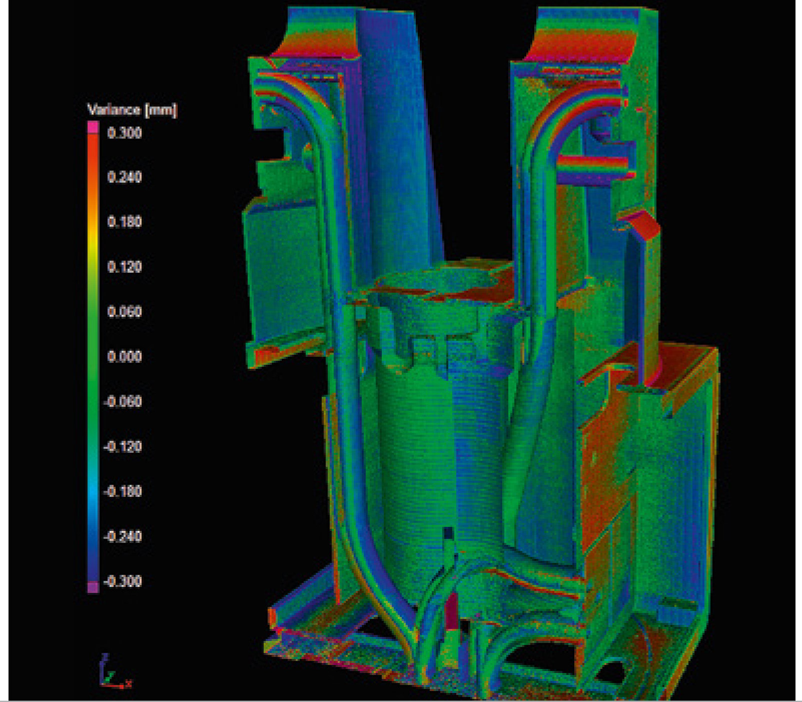
	ZEISS Xradia Versa	ZEISS Smartproof 5	
Sq	3.9	3.75	µm
Ssk	-0.174	-0.111	
Sku	3.52	3.57	µm
Sp	14.8	14.8	µm
Sv	26.4	23.8	µm
Sz	41.2	38.6	µm
Sa	3.06	2.93	µm

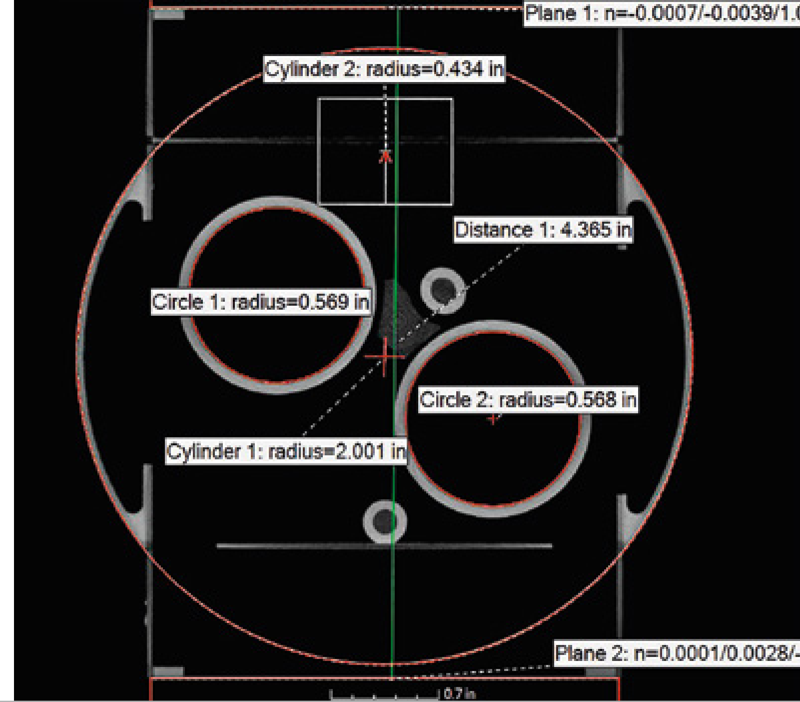
Dimensional Quality Inspection

X-ray Computed Tomography (X-ray CT)

Dimensional accuracy of additively manufactured parts is critical, as it will affect the actual system performance. Given the extreme complexity of those parts, X-ray CT is the only option for non-destructive and accurate metrology of complex internal and external features.

\> Sample measurements of internal features using X-ray CT

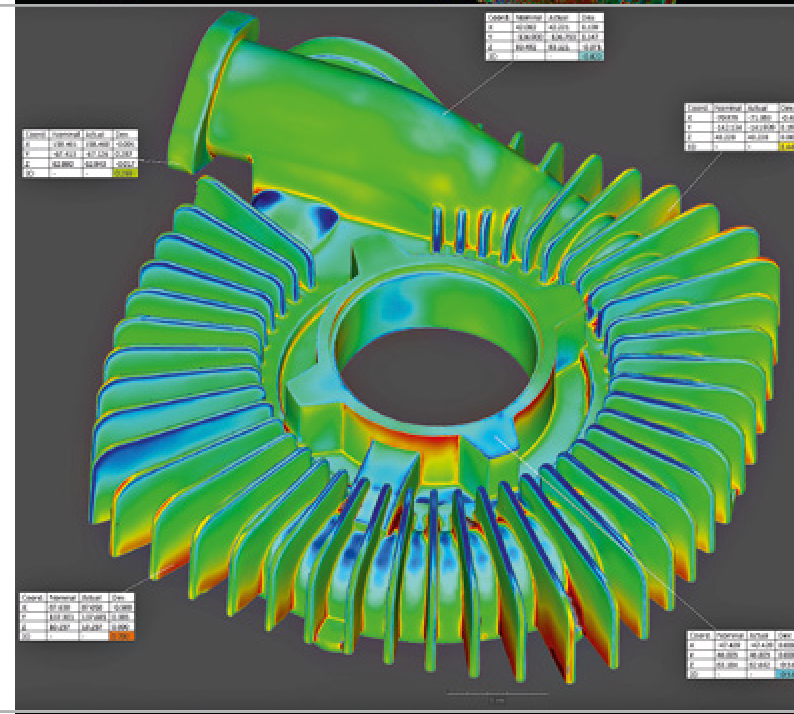


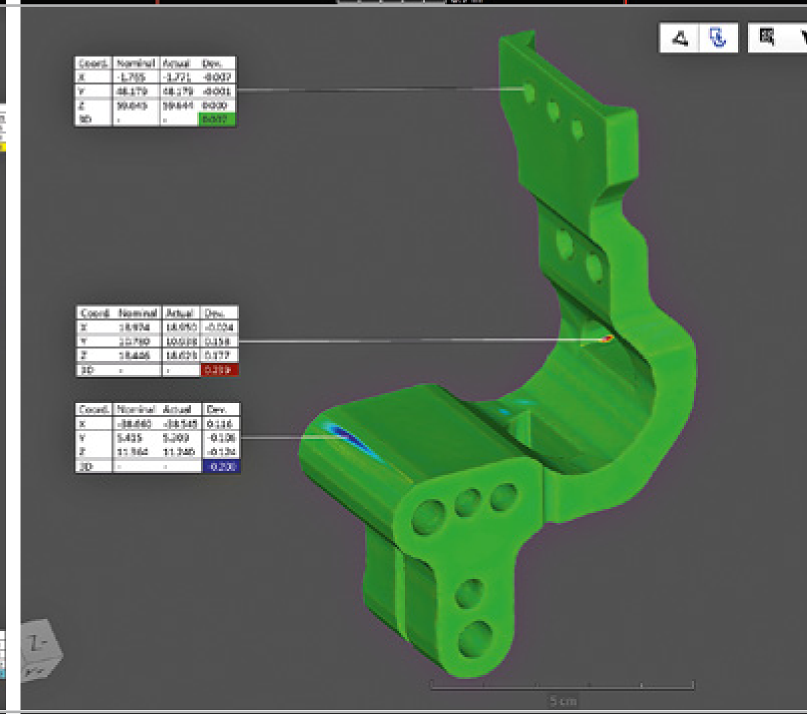


3D Scanning

3D scanning offers an alternative to X-ray CT for parts that have no complex internal features and whose external shape, form, and size are of interest.

\> Dimensional analysis of parts using 3D scanning

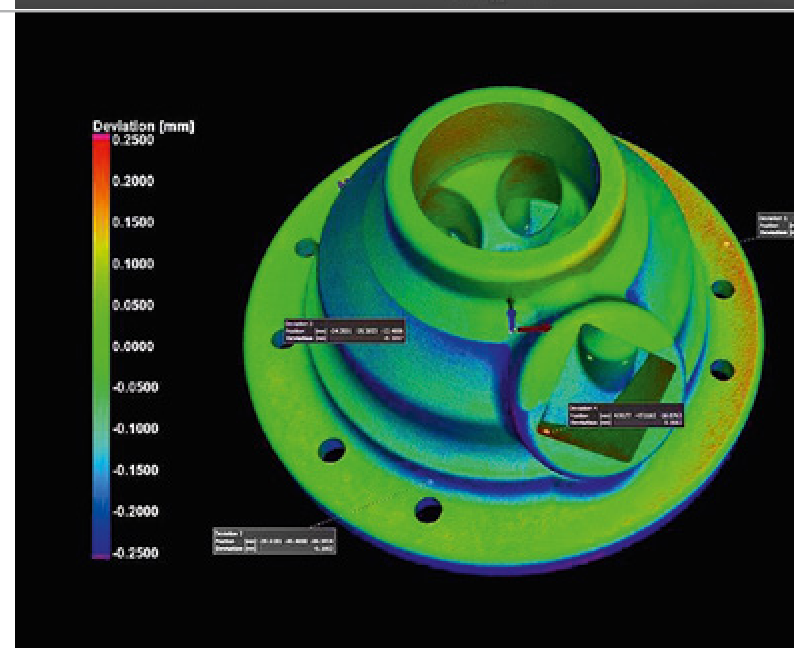


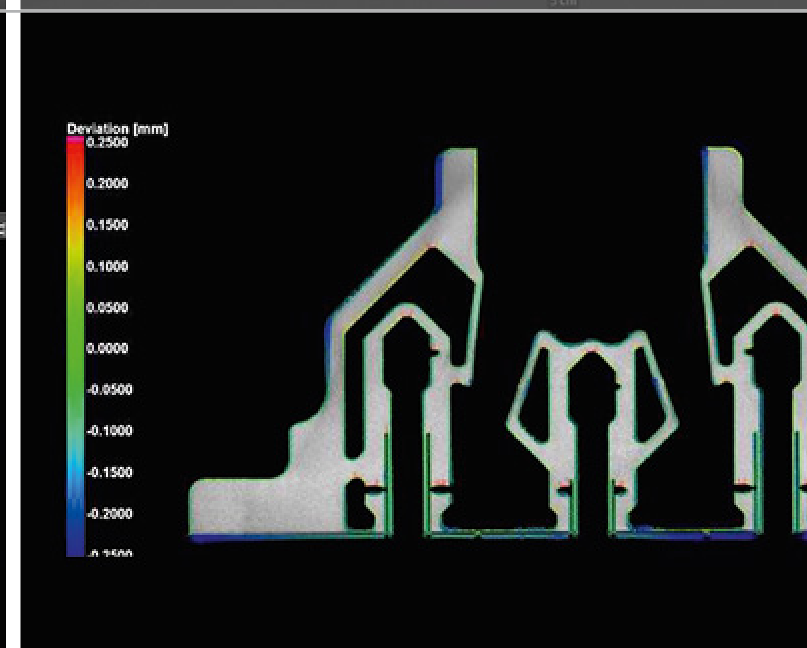


Dimensional Metrology

Printed parts are often assembled into larger systems. Therefore, dimensional accuracy is just as critical as it is for subtractively produced parts. The ability to verify critical dimensions is necessary to validate the quality of the build.

\> Dimensional analysis of internal features using X-ray CT

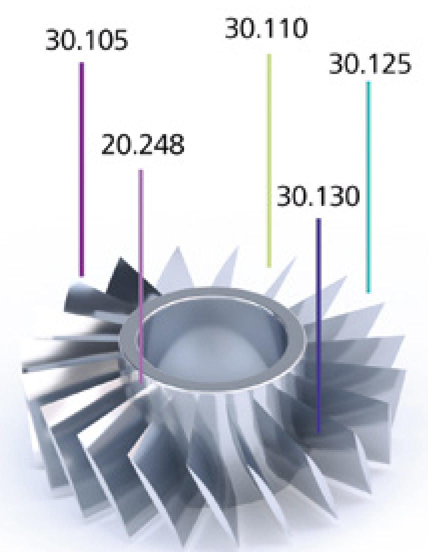


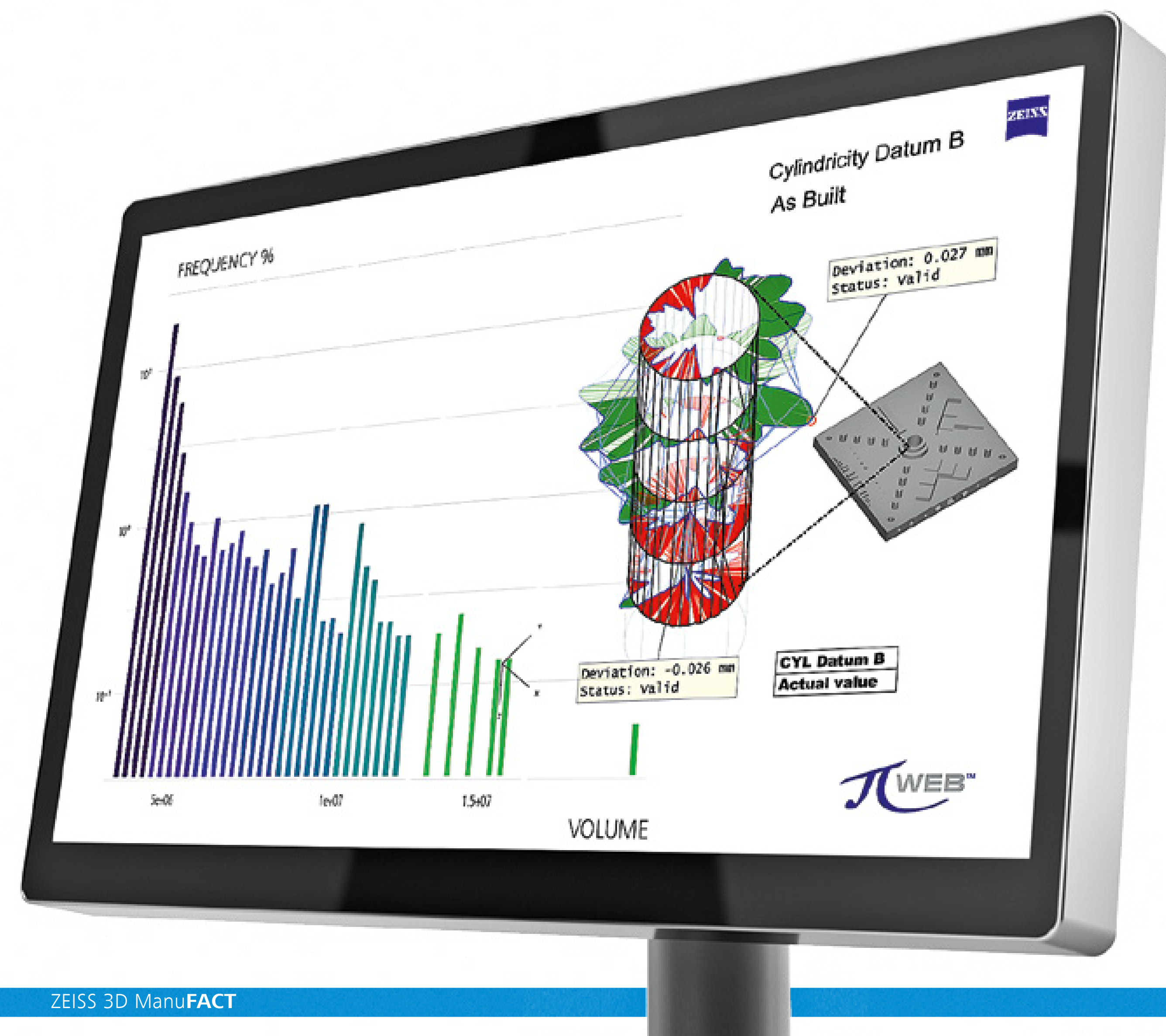


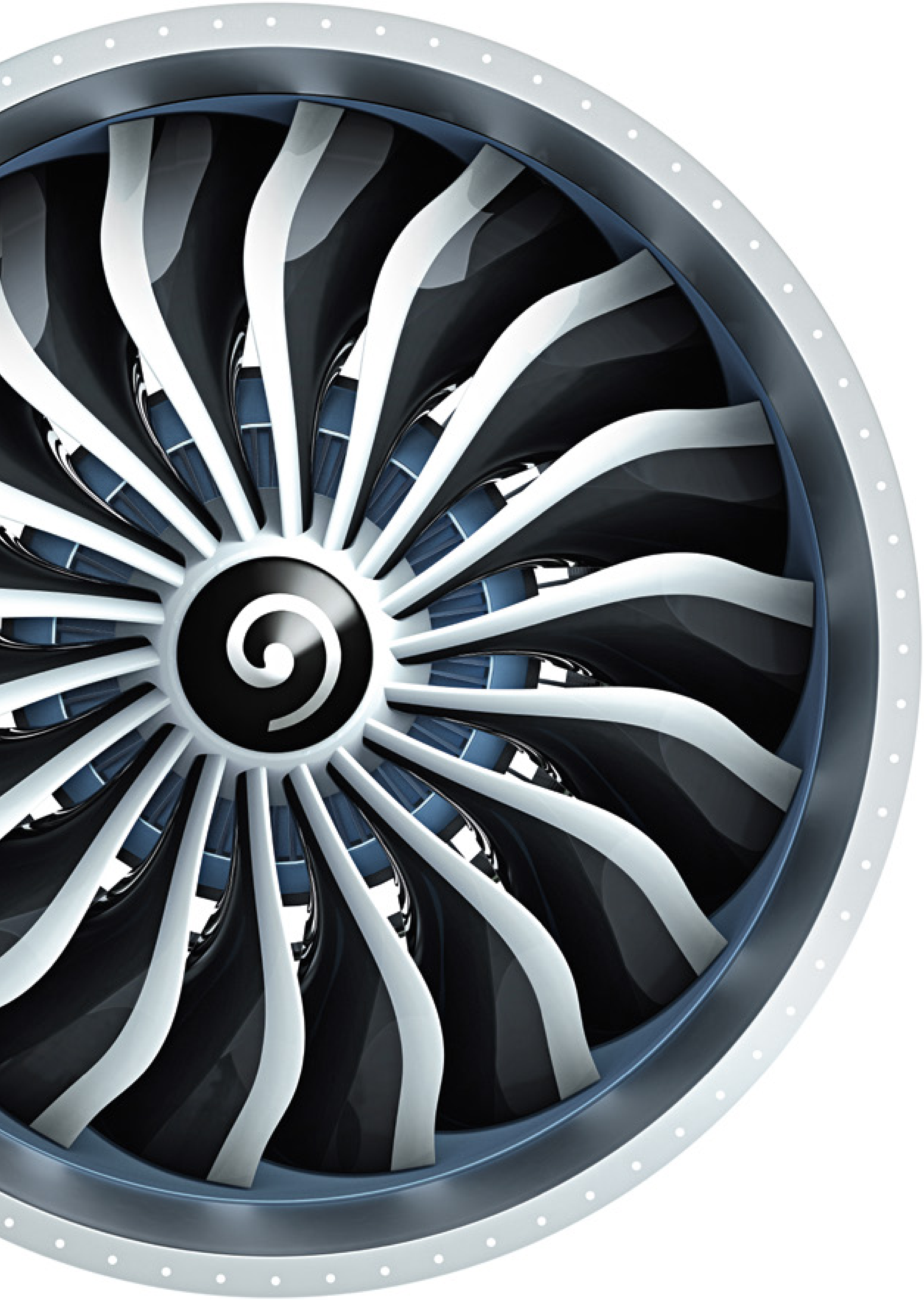
Process Data
Statistics and Analytics

Collection and analysis of data across the entire process chain with ZEISS PiWeb provides a deep understanding of how process changes might correlate with different dimensional and material properties. Clear visual representation and correlation of results across all process steps help to quickly and more efficiently develop printing strategies while increasing yield.

ZEISS PiWeb



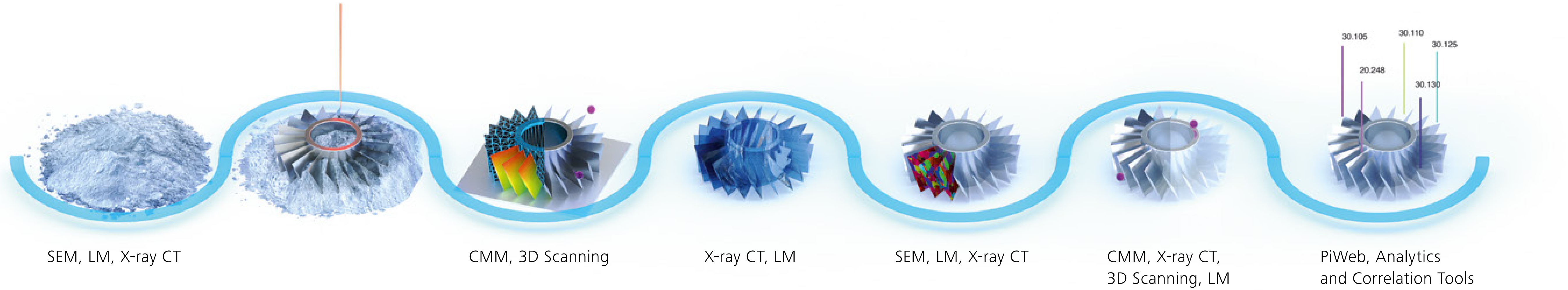




ZEISS 3D Manu**FACT**

Increasing productivity with
the holistic solution from ZEISS.

ZEISS Portfolio



Scanning Electron Microscope (SEM)

ZEISS Sigma

High-performance SEM with EBSD enables micro-structural crystallographic characterization and powder analysis.

ZEISS EVO

Professional grade SEM with EBSD enables micro-structural crystallographic characterization and powder analysis.

Light Microscope (LM)

ZEISS Smartproof 5

High-resolution and high-speed optical profilometer for detailed surface analysis.

ZEISS Axio Observer

Inverted optical microscope for material analysis and detailed inspection of build patterns and cross sections.

ZEISS Smartzoom

With the digital microscope it is possible to view the sample from multiple directions while maintaining focus for speed and simplicity of use.

X-ray Computed Tomography (X-ray CT)

ZEISS Xradia Versa

High-resolution X-ray CT to support detail analysis of powders, surfaces, and structures with voxel size down to 70 nm.

ZEISS METROTOM

High accuracy X-ray CT to support dimensional verification and defect analysis of parts with complex internal and external structures.

ZEISS VoluMax

High-speed X-ray CT to support automated dimensional verification and defect detection of mass production quantities.

Coordinate Measuring Machine (CMM)

ZEISS DuraMax HTG

The compact shop floor CMM allows investigation of post-build processes, showing any influences on dimensional accuracy of finished parts.

3D Scanning

ZEISS COMET

The 3D scanner offers a high measuring speed, quickly showing any post-build process influences on the dimensional accuracy of a finished part.

ZEISS PiWeb

ZEISS PiWeb

ZEISS PiWeb is a scalable IT solution for quality data management which helps you organize the information flow resulting from Industry 4.0.

From Powder to Performance.

ZEISS 3D Manu**FACT**

// INNOVATION
MADE BY ZEISS

More information on:
www.zeiss.com/metrology/additive-manufacturing

EN_60_025_0016I Printed in Germany CZ-IV/2018 U00