SIEMENS

Overview of X-ray Technology and Competence offered by Corporate Technology

Industrial X-ray for Nondestructive Testing

Nondestructive Testing (NDT) with X-rays: Our offer at a glance

High-tech X-ray lab for 2D- and 3D-inspection

- 2D X-ray radiographs provide a "fast look inside"
- CT-scans produce 3D volume data for inspection and dimensional measurements
- Advanced setups: Fast CT and Tomosynthesis (laminar CT)

Unique software platform Sixtos 3.0 with reconstruction suite CERA

- New concept and easy-to-use platform for 2D and 3D X-ray systems
- Fast CERA reconstructions provide high image quality
- Adaptable platform for multi-purpose use integrating all hardware components

## Concept and build of customized systems

- Success stories of systems built in the past
  - CT-scanner for customer I IA(Amberg)
  - Gantry scanner for customer Corning (Berlin)
  - Customized 2D system for customer E P SU (Mülheim)
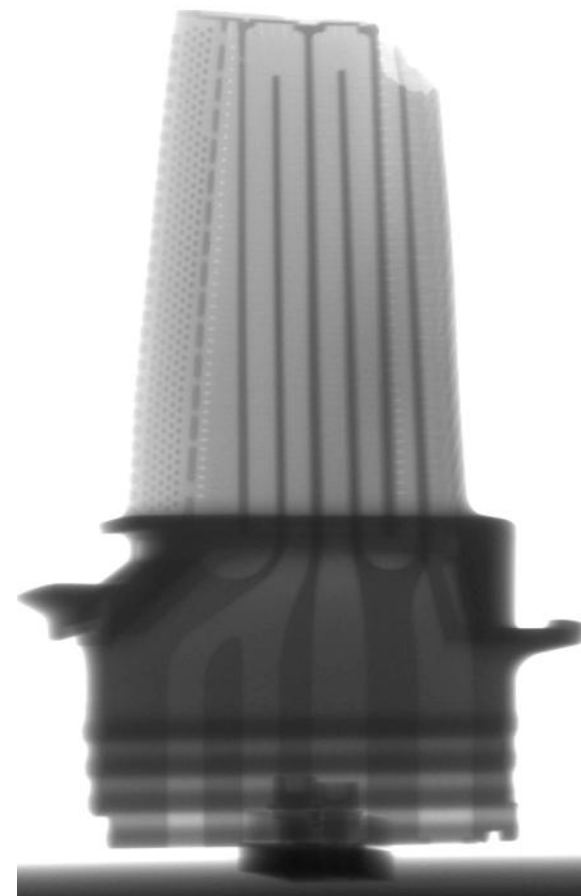
Consulting and feasibility studies

- Consulting built on broad expertise and network in the field of X-ray technologies
- Feasibility studies to various challenges based on fundamental experimental tests as well as simulation studies

2D X-ray inspection
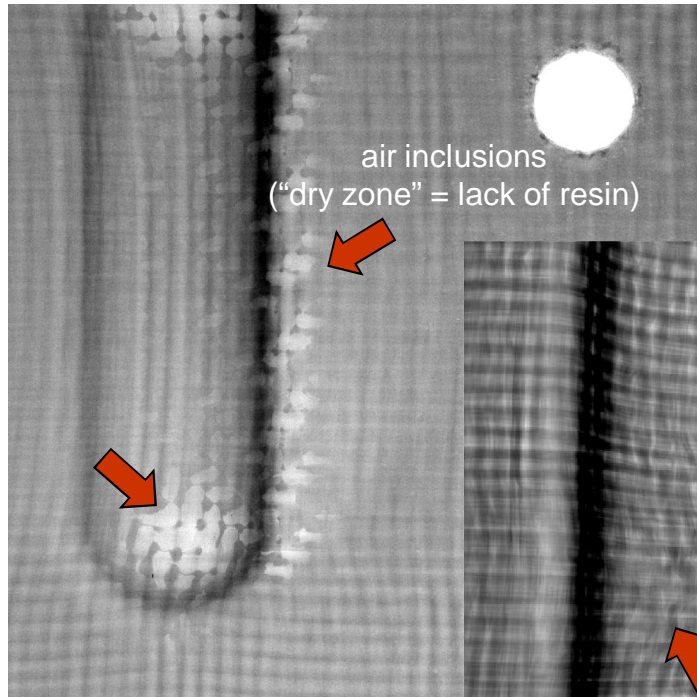
2D radiographs are a fast way „to look inside"
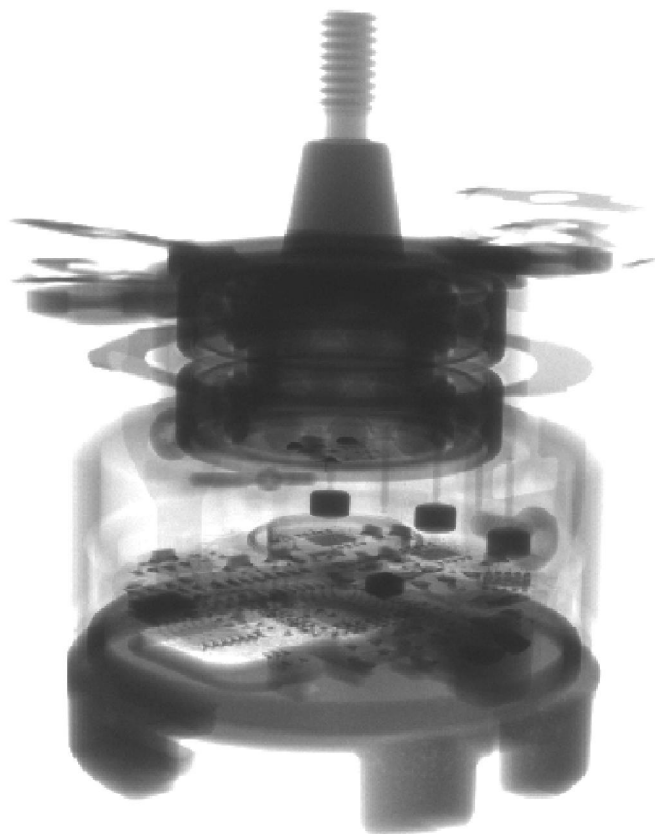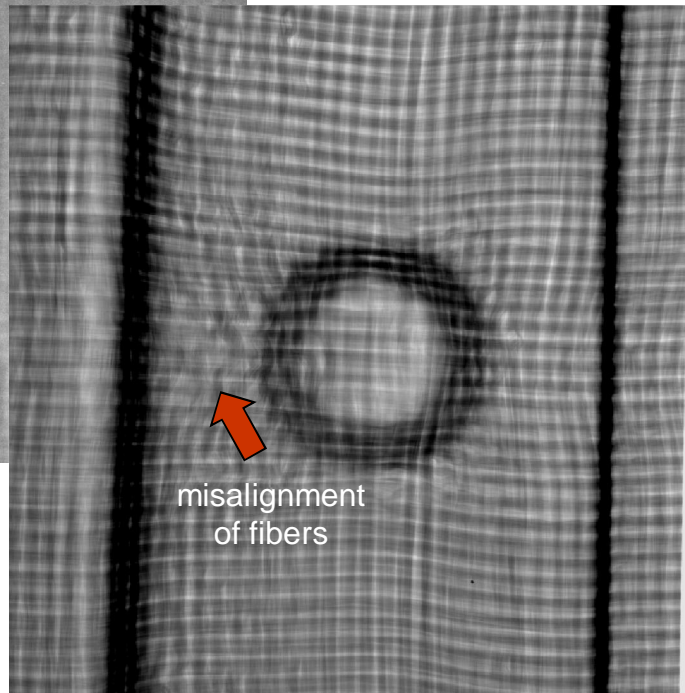

Rotary encoder

Turbine blade made from Inconel alloy
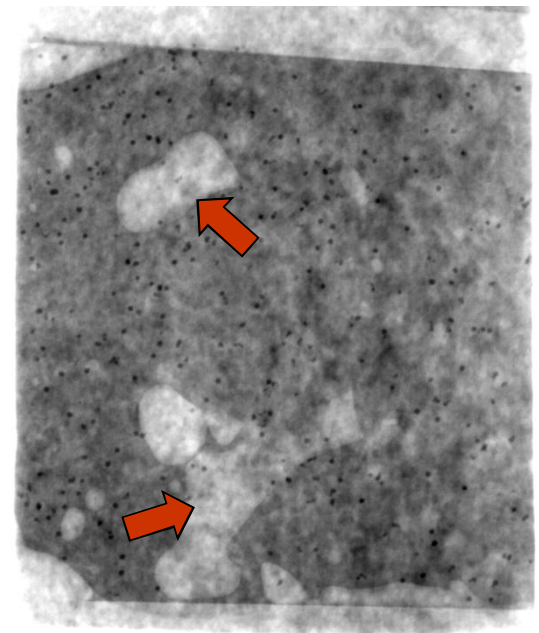(LINAC used for inspection)

2D X-ray inspection

2D radiographs are a fast way „to look inside" and detect faults

air inclusions
("dry zone" = lack of resin)

Carbon- and glass-fiber
reinforced plastics

misalignment
of fibers

Air inclusions in
gluing interface

(black dots: tiny glass pellets)

2D X-ray inspection

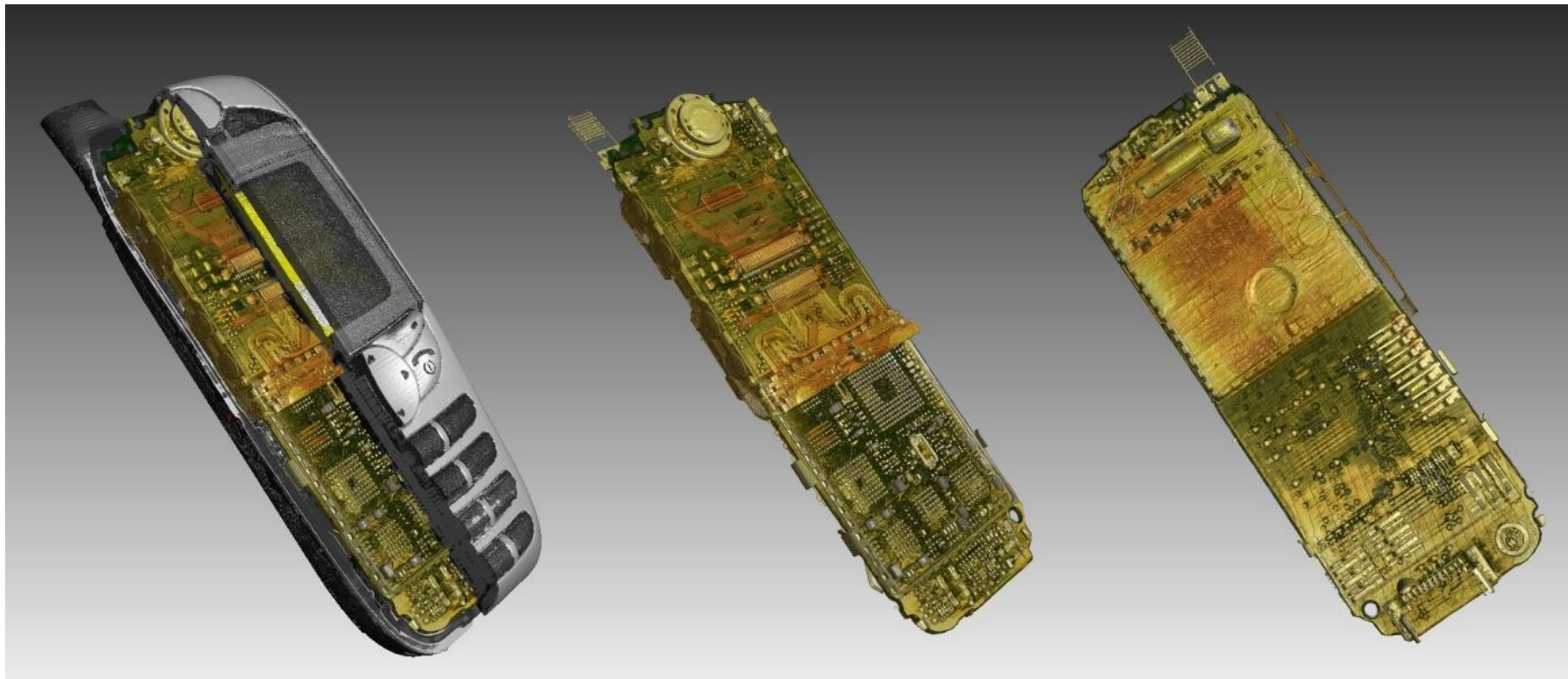2D radiographs are a fast way „to look inside" and detect faults:

Even single fibers/rovings with diameters of ~ 5-10µm are visible.

Carbon- and glass-fiber reinforced plastics

Air inclusions in gluing interface

(black dots: tiny glass pellets)
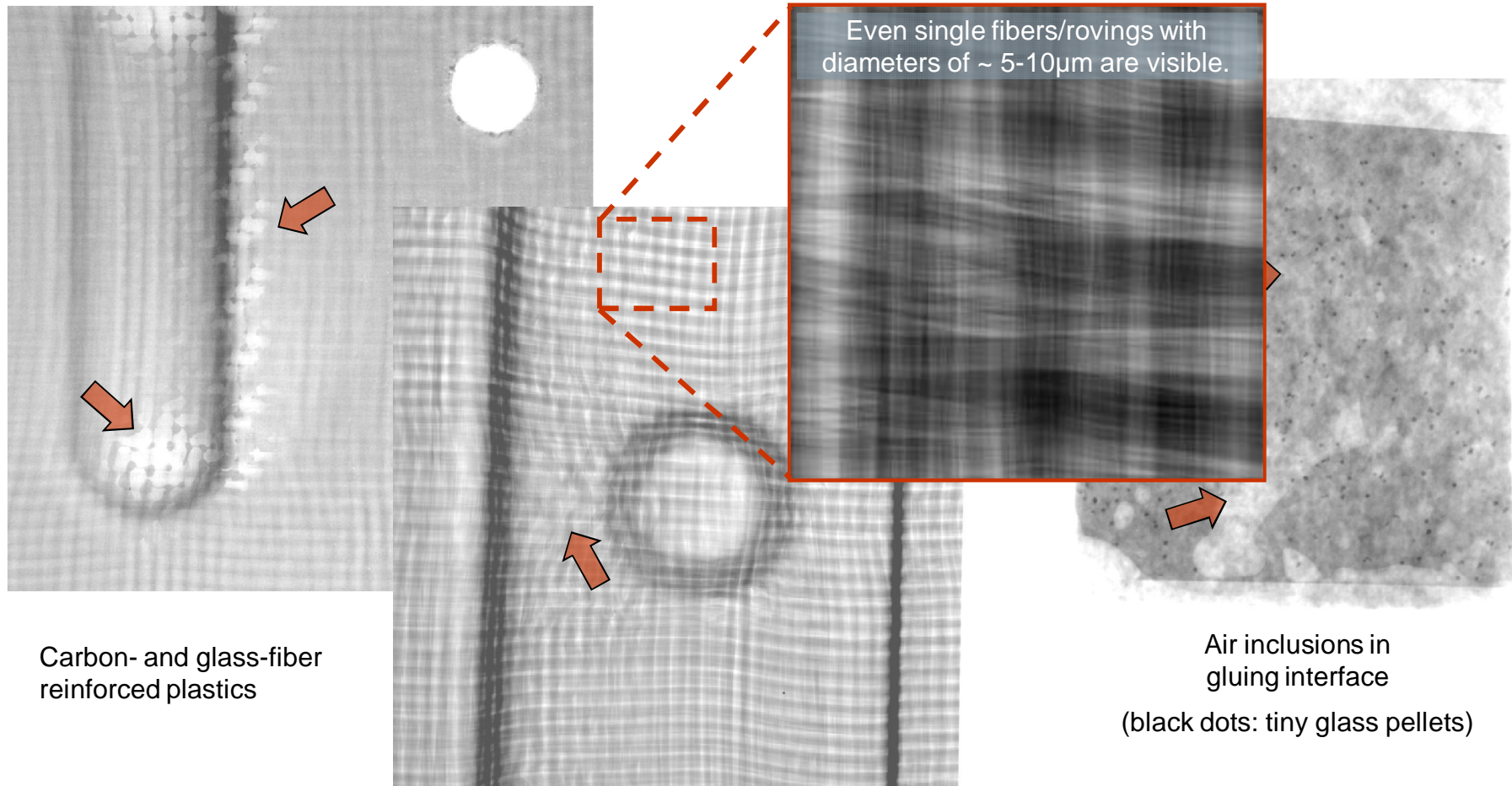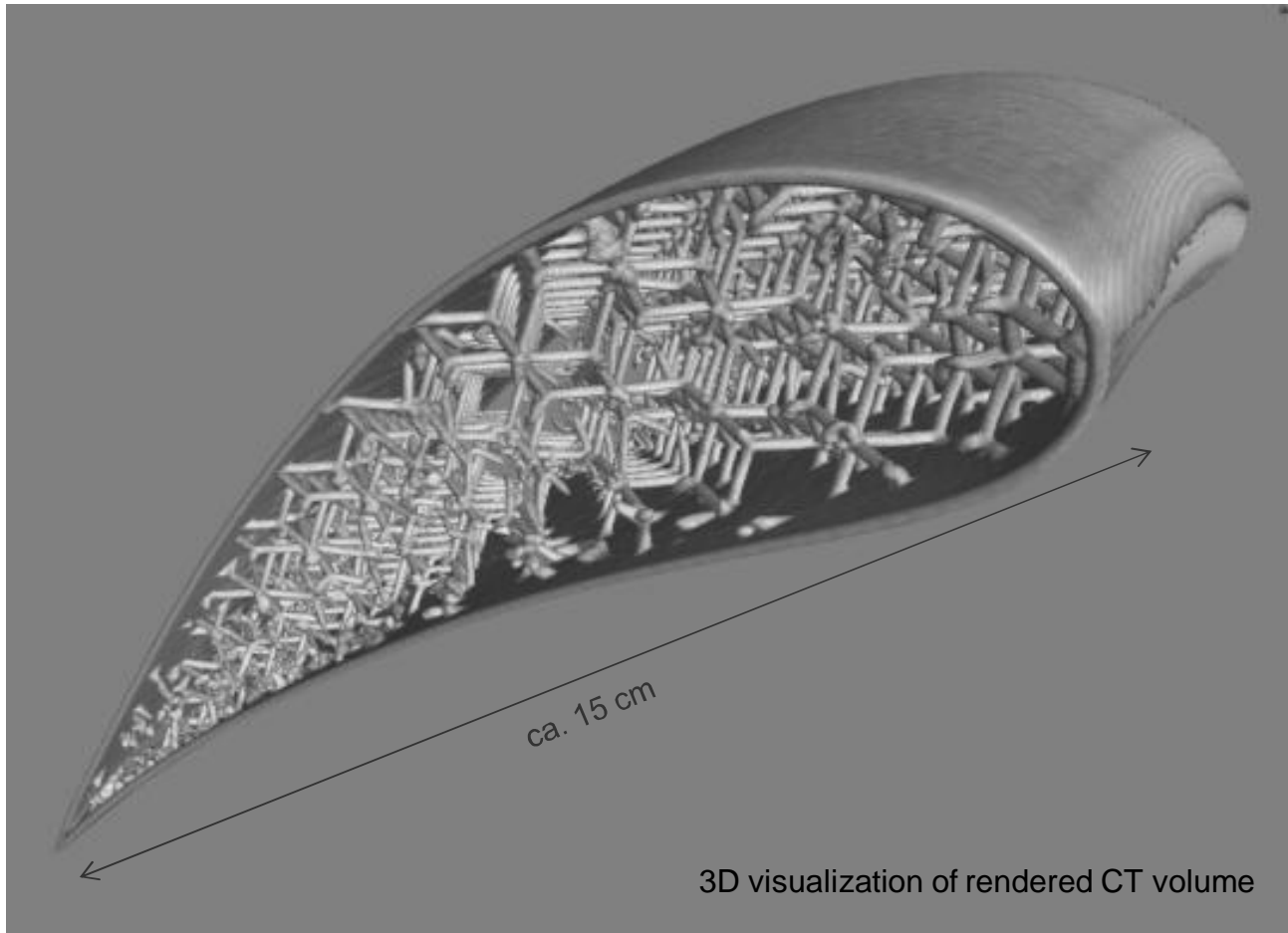
X-ray Computed Tomography
3D inspection

CT scan of Siemens mobile phone SL45

Visualization of the volume by VGStudio MAX for coloring and segmentation of individual components
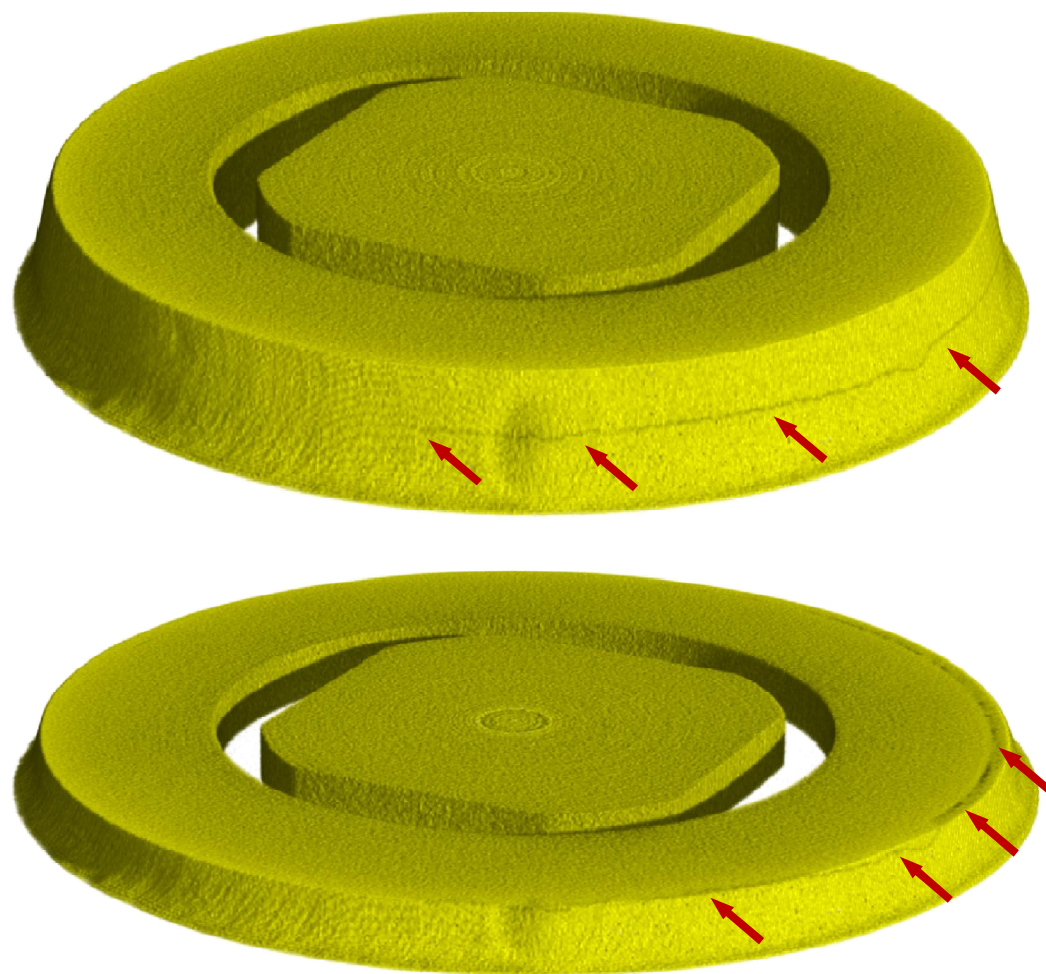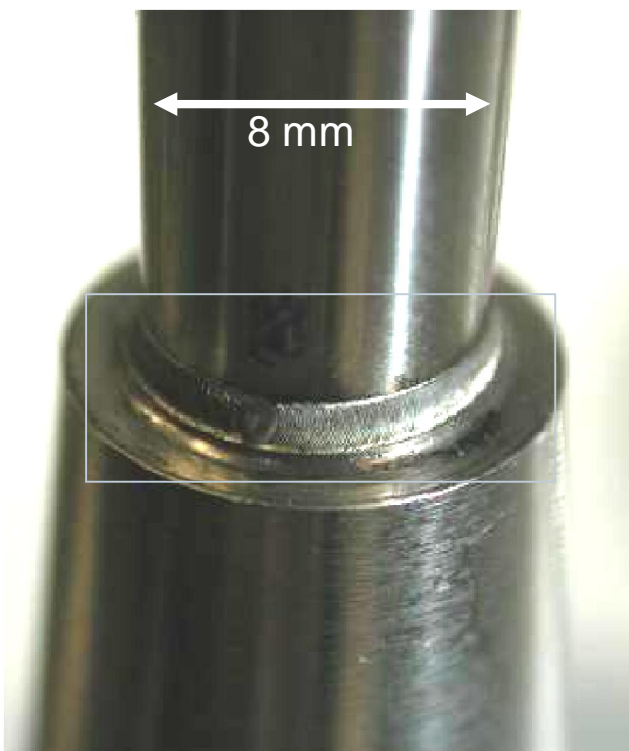
X-ray Computed Tomography
3D inspection

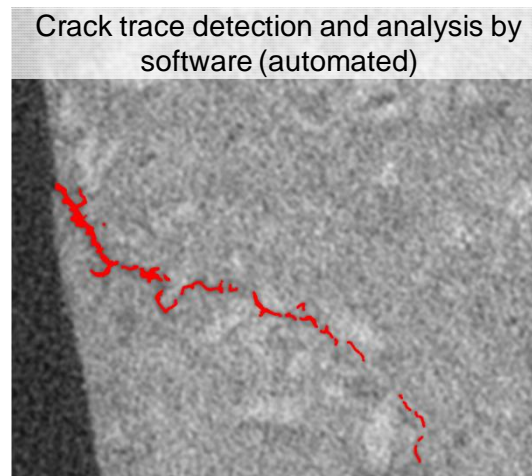CT scan of 3D-print (laser-sintered) sample part of a turbine blade

ca. 15 cm

3D visualization of rendered CT volume

X-ray Computed Tomography
3D inspection

Classical NDT: Crack detection in laser welds

8 mm

X-ray Computed Tomography
3D inspection

Classical NDT: Software-automated crack detection in ceramic heat shields

Heat shields in combustion
chamber of gas turbine

Ceramic heat shield (photo)

ca. 20cm

Ceramic heat shield
(CT volume, 3D-visualization)

CT slice of tomographed heat shield,
crack visible

Crack trace detection and analysis by
software (automated)
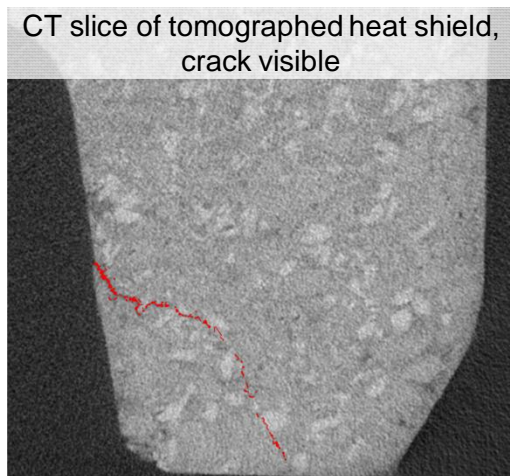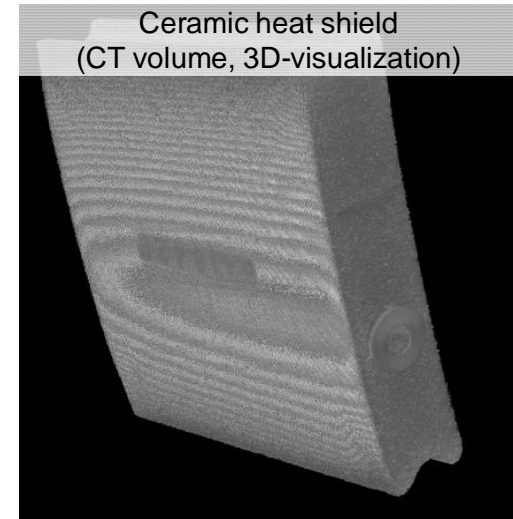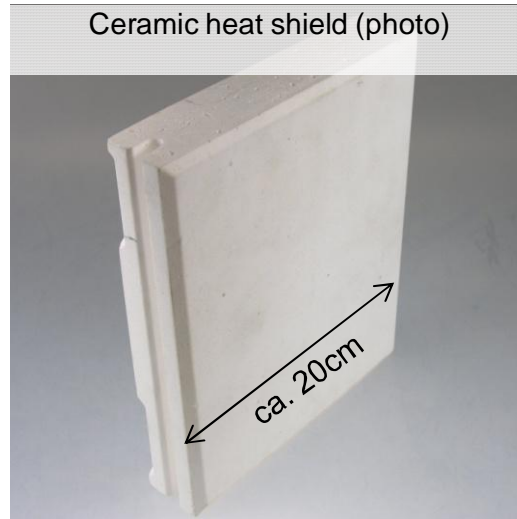
X-ray Computed Tomography 3D inspection

CT slices of carbon fiber reinforced polymer showing air inclusions within resin layers
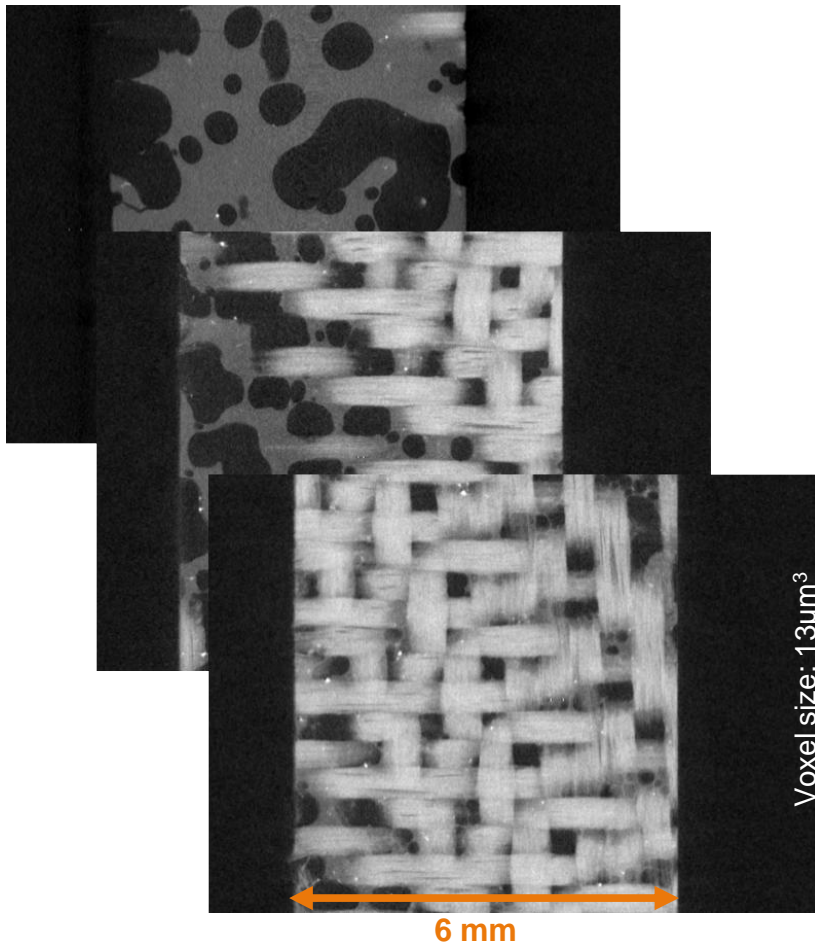
CT slices showing four layers of different orientation in carbon fiber reinforced polymer

Voxel size: 13μm³

6 mm

4 stacked layers
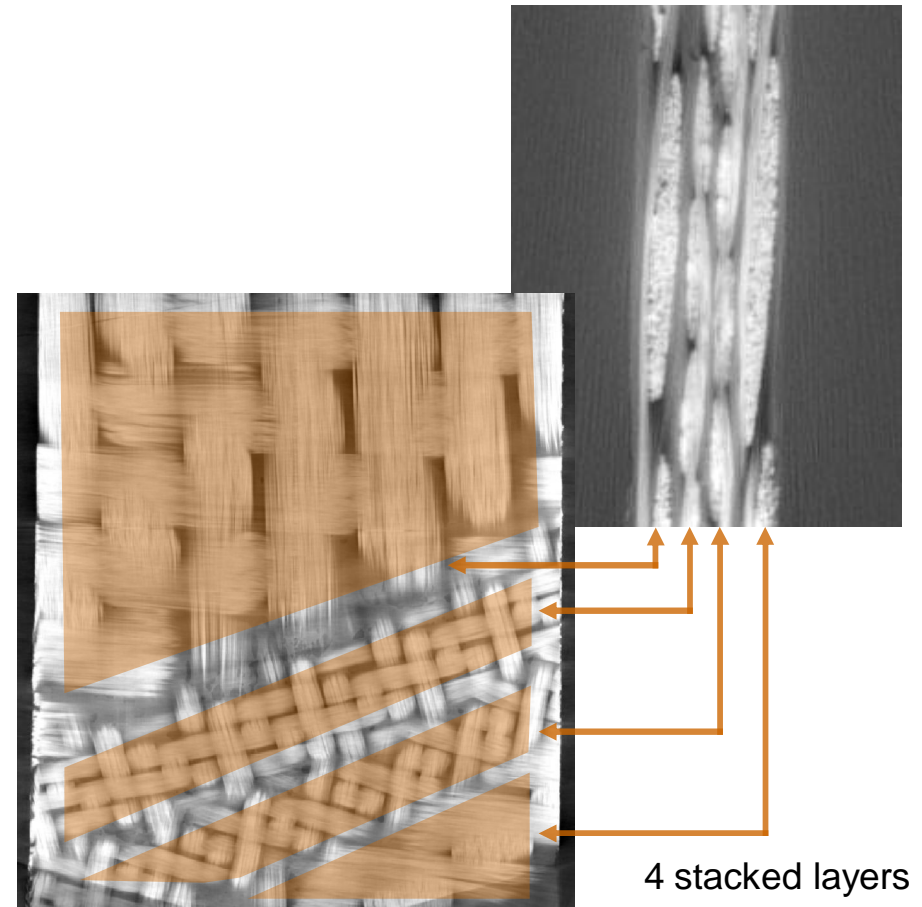
X-ray Computed Tomography
Nominal/Actual-comparisons

X-ray CT data

CAD data

Nominal/Actual-comparison yields
color-coded information about dimensional
deviations from CAD-model

| | Delta ≤400µm |
| | Delta ≤ 50µm |
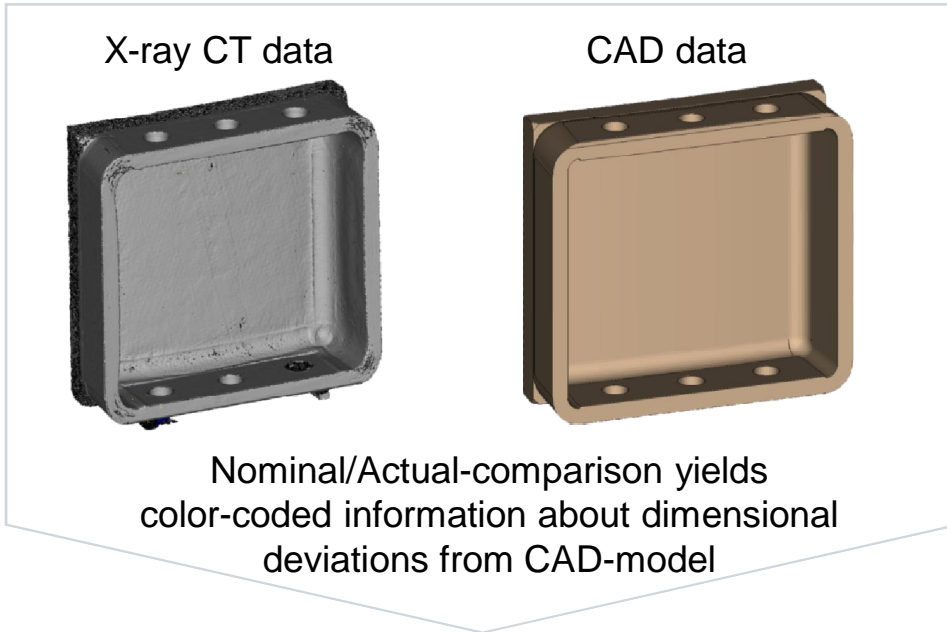
Also applicable for larger parts:

Abweichung [mm]
0.75
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
-0.75
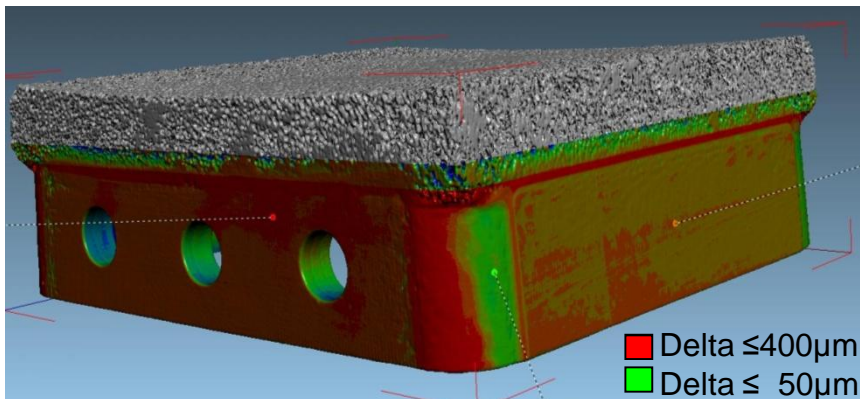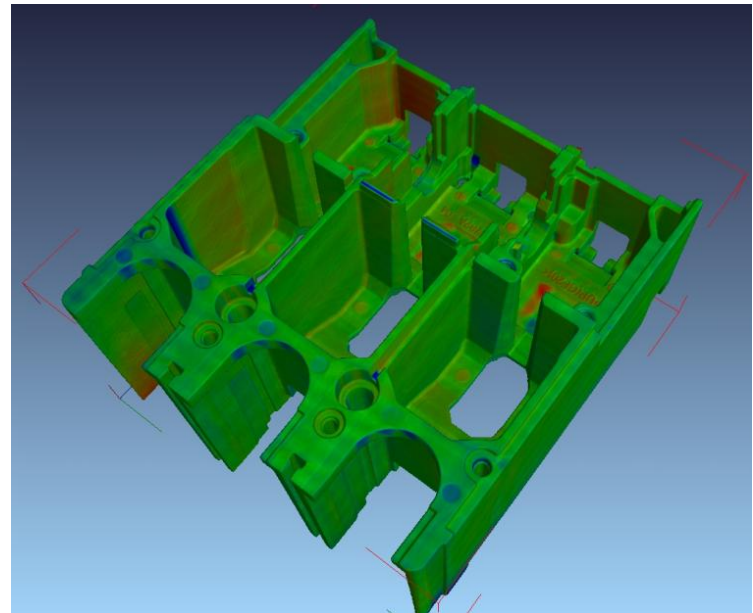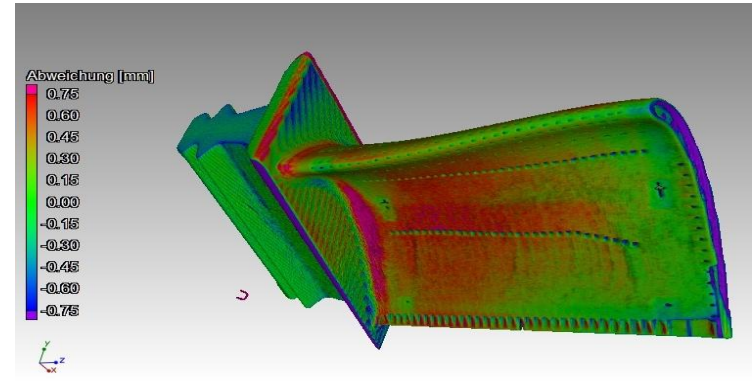
X-ray Computed Tomography
Fast CT

- Fast CT allows 'in-situ' inspection during production process
- High-power X-ray source from Siemens Healthcare: max. 85kW
- High-power X-ray tube leads to improved image quality (= better signal-to-noise ratio)
- Shorter exposure times
- Complete CT within < 30 seconds

High-power X-ray tube Megalix
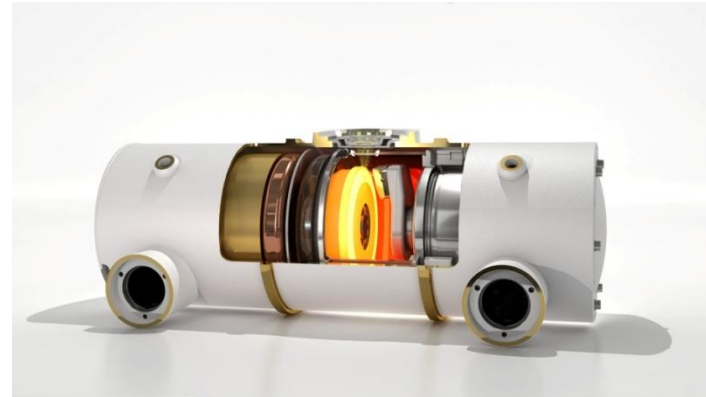
3D-CT results: CT scan time only **24 seconds**!
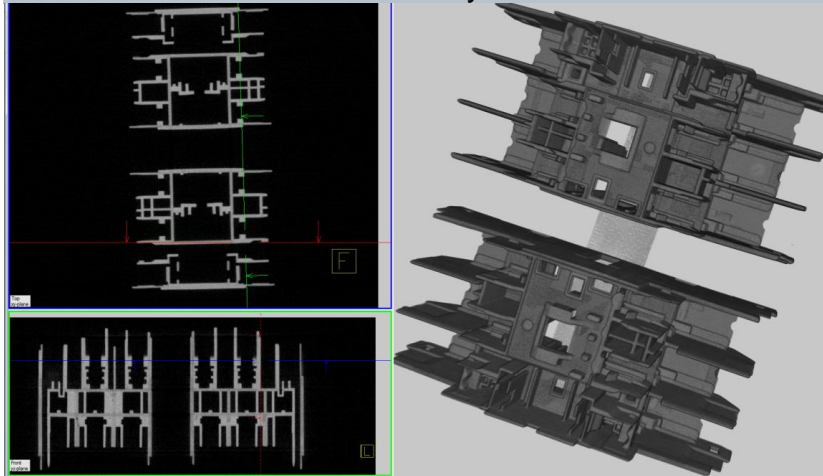
Fast detection by flat-panel imager

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Example object with cracks

Detector mode: 1x1 (=10fps)

720 Proj. (72s Scan)	360 Proj. (36s Scan)	180 Proj. (18s Scan)	90 Proj. (9s Scan)

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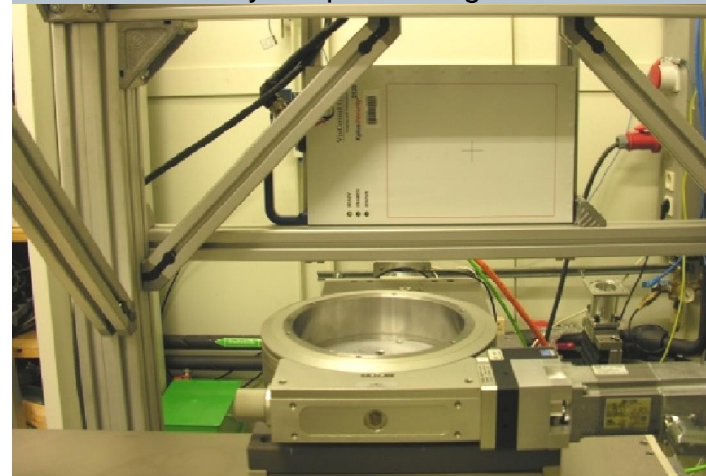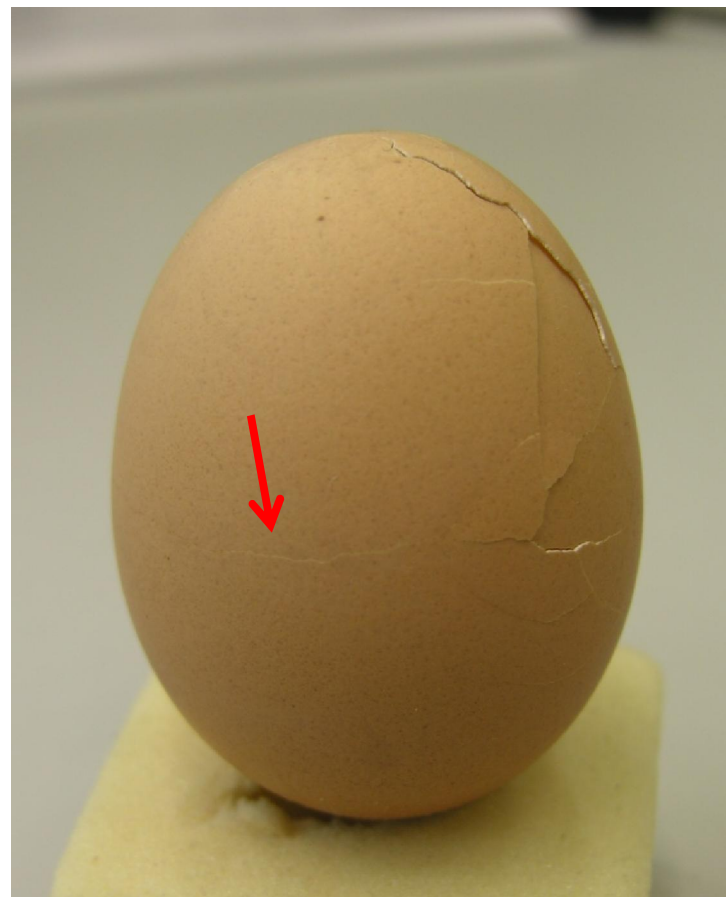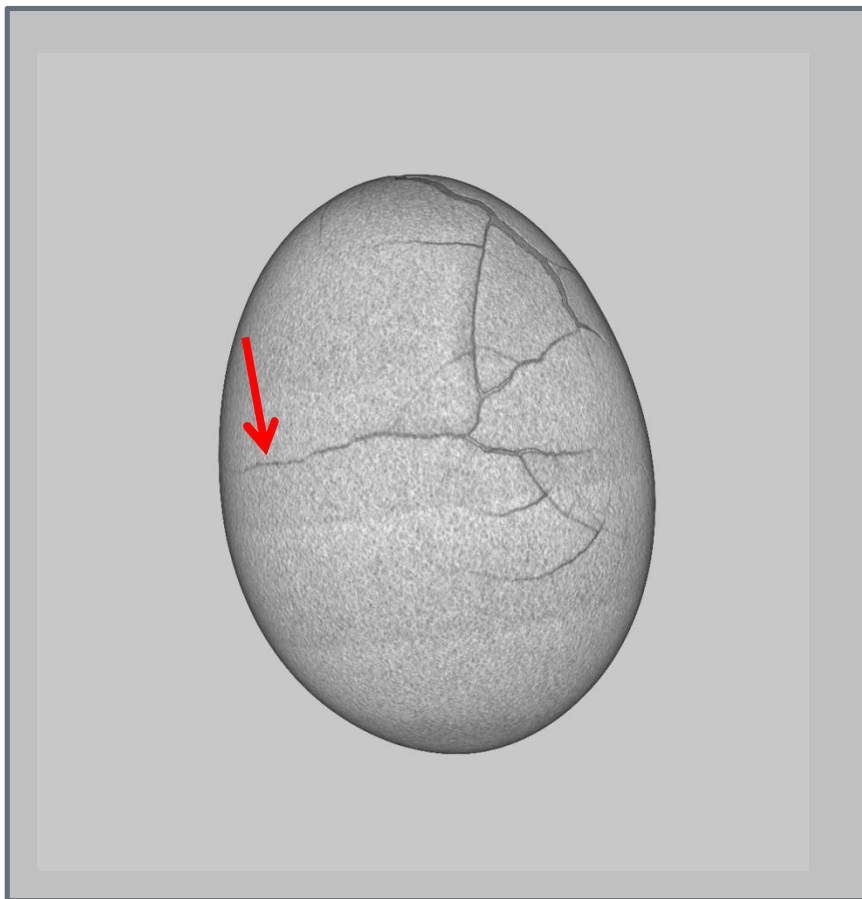
Unique software platform Sixtos 3.0 with reconstruction suite CERA

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Concept and build of customized systems

- Success stories of systems built in the past
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Consulting and feasibility studies

- Consulting built on broad expertise and network in the field of X-ray technologies
- Feasibility studies to various challenges based on fundamental experimental tests as well as simulation studies

Customized X-ray systems:
We design and build prototypes

Example 1:   Universal lab system (customer: I IA, Amberg)

Multi-purpose CT scanner system for offline inspection of plastic assemblies.
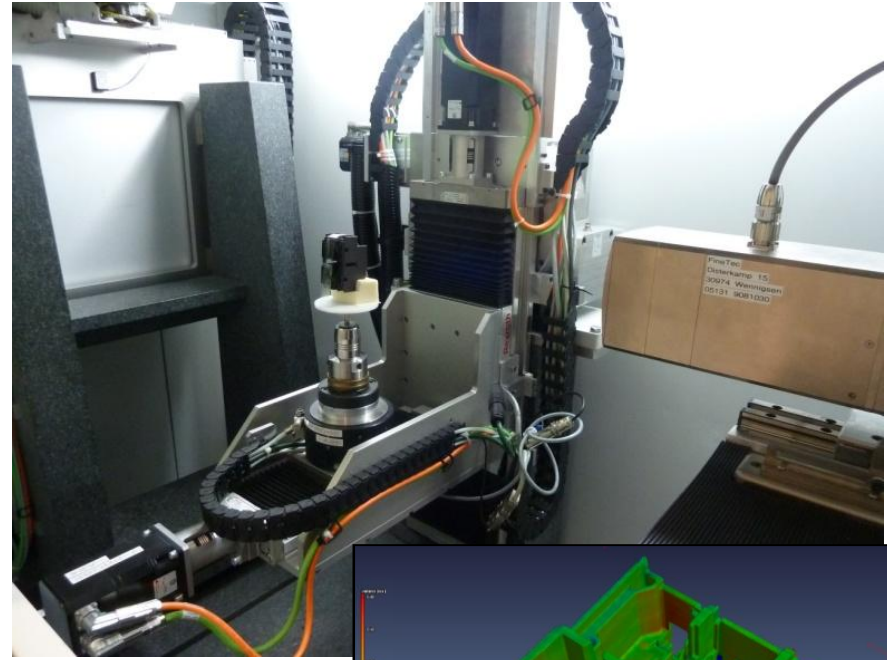
Application example:
nominal/actual-comparison of
tomographed contactor housing
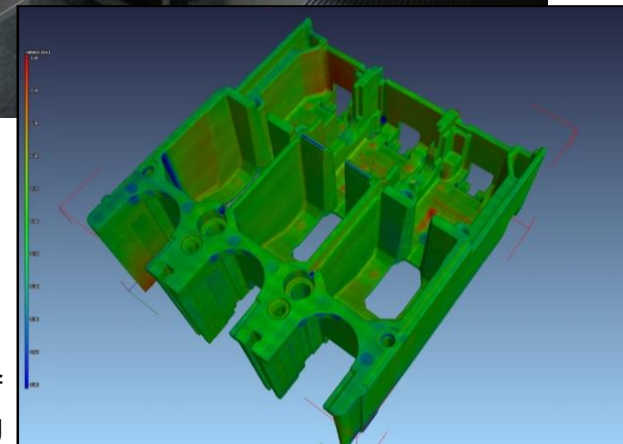
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Example 2: Lab system for glass fiber cable inspection
(customer: Corning Cable Systems, Berlin)

Customized system based on gantry scanner from Healthcare
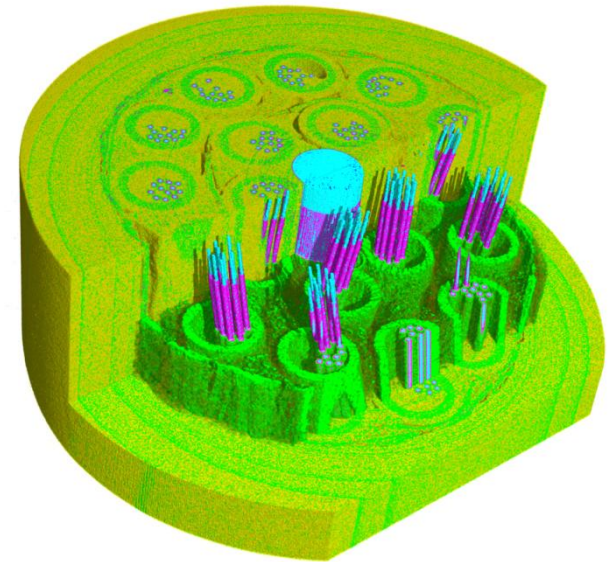
CT-reconstructed volume:
Scanning glass fiber cables
with rotating gantry
(10 µm resolution)

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X-ray Software:
SIXTOS 3.0 – a unique way to CT

SIXTOS – **SI**emens **X**-ray **TO**mography **S**oftware

- Complete control and reconstruction software for X-ray inspection systems

Benefits

- Perkin-Elmer, Varian, Comet, FineTec and Siemens interfaces already implemented
- Further hardware can easily be integrated
- Switch between different detectors and X-ray tubes, even at runtime
- Available acquisition trajectories: FDK, TXR, helix, half-cone beam and tomosynthesis
- Various reconstruction types including iterative reconstructions run on high-speed Tesla-GPUs
- Ongoing developments/updates with respect to speed, features, artifact reduction etc.

Technology & Competency

- Uses SINAMICS: Siemens high-precision motion control

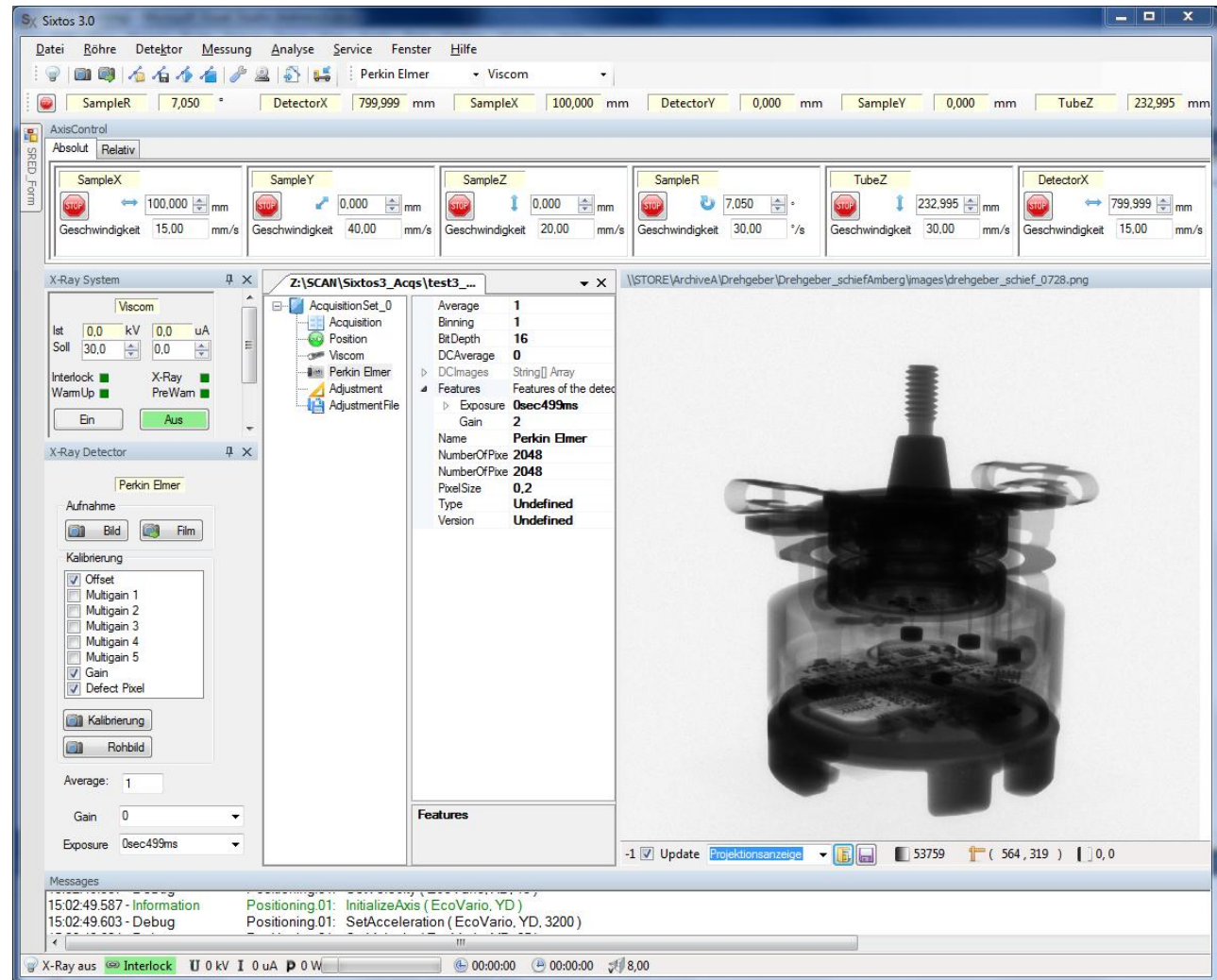- Uses CERA: Siemens software for high-speed GPU-accelerated reconstruction

- Innovative and proprietary algorithms

SIXTOS 3.0 – a unique way to CT Acquisition view
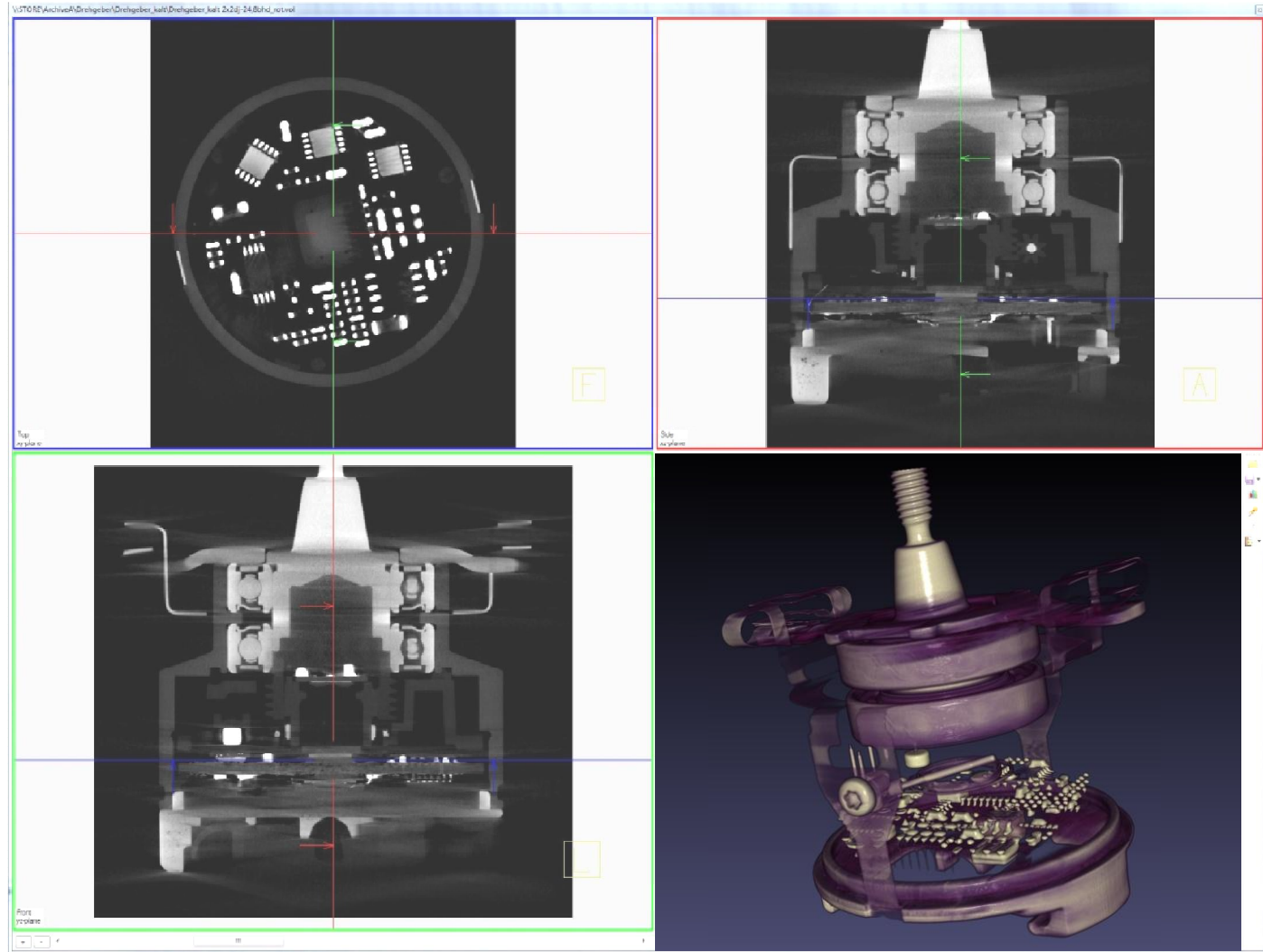
Customizable GUI

- Modules can be re-arranged in any fashion by customer needs.
- Modular GUI-components can be imported to customer's own stand-alone application.

SIXTOS 3.0 – a unique way to CT
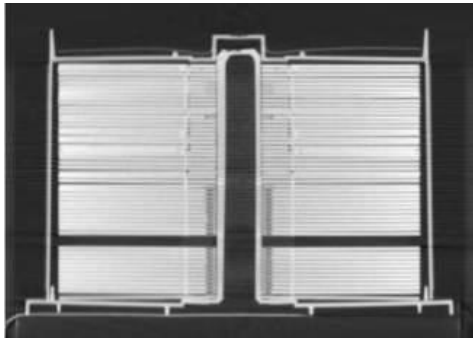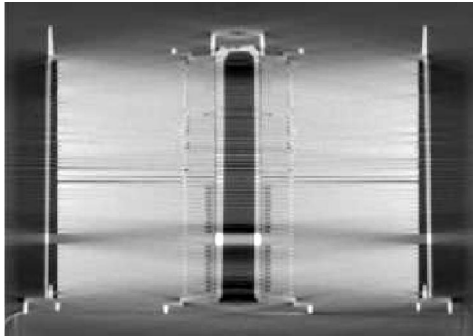# Built-in volume visualization

- Customized 3+1-viewer based on CERA viewer
- Adjust colors and opacity
- Zoom, rotate, pan, sliding functions
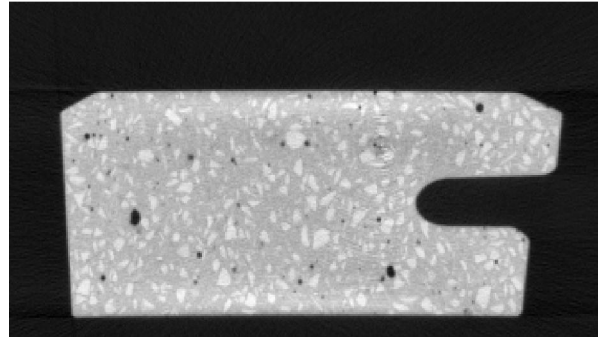- Comfortable and easy control by user

SIXTOS 3.0 – a unique way to CT
Typical CT artifacts and how we correct them

Cone beam	**Scattering**	**Limited penetration**
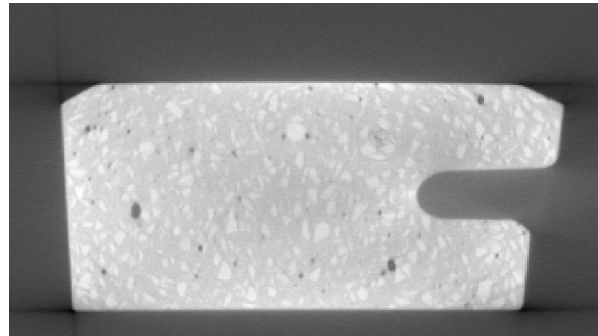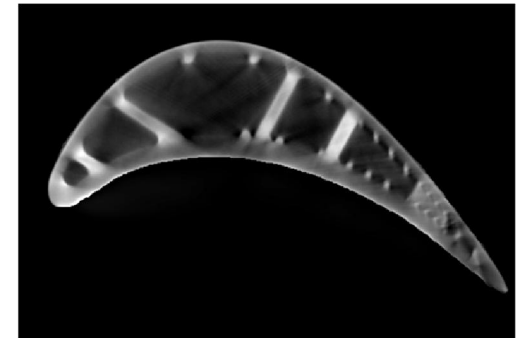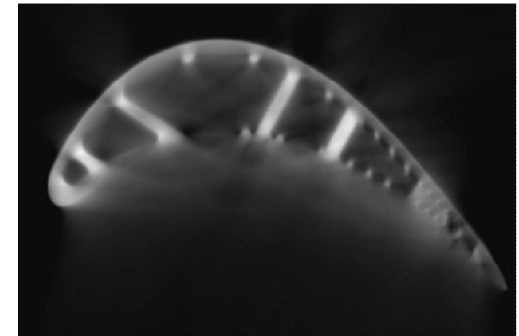
Cause:	Cone-shaped beam, missing information	Scattered photons hit detector	Material too thick to be penetrated
Effect:	Typical cone beam artifacts	Reduced contrast	Blurred edges, missing information
Solution:	**Theoretical Exact Reconstruction (TXR)**	**New CT scatter correction technique**	**Iterative reconstruction with prior knowledge**

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X-ray Consulting

For more than 25 years, we have invested into research and development in the field of industrial X-ray inspection. Broad expert knowledge, as well as a valuable network to internal and external partners enable us to offer consulting to questions related to X-ray inspection.

Network to internal and external partners (selection):

- Siemens Healthcare
- TU München (Technical University)
- Fraunhofer EZRT
- Bundesanstalt für Materialforschung und -prüfung (BAM)
- Miscellaneous suppliers of X-ray components

Linear accelerator
(Source: Siemens Healthcare)

X-ray Feasibility Studies

At Siemens CT in Munich, a wide range of X-ray technology and supporting software allow us to perform fundamental experimental tests. Furthermore, simulation packages complement our equipment.

Both together present a basis for tackling new challenges, improving existing technology, or finding customer-specific solutions.

Technology & Competency

- BAM aRTist simulation suite (**a**nalytical **R**adiographic **T**esting **i**nspection **s**imulation **t**ool)
- Simulation programs developed by Healthcare
- Various source code for testing different reconstructions and physical influences

Blade airfoil simulation study using different X-ray spectra

225 kV · 450 kV · 300 kV · 800 kV
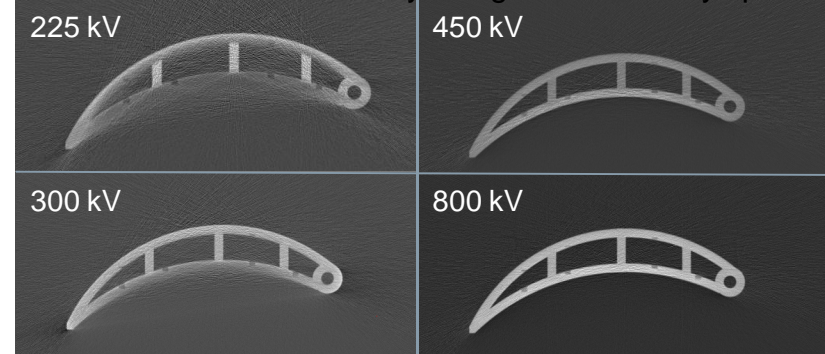
Thank you for your interest!
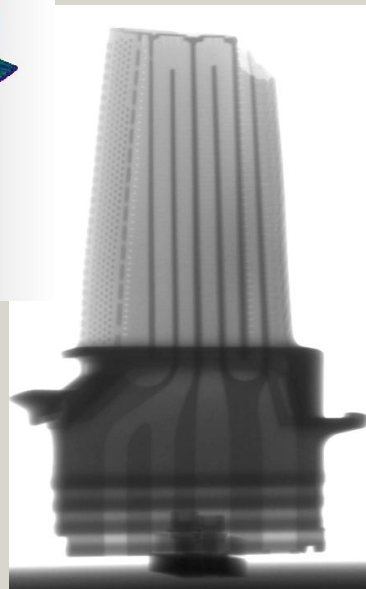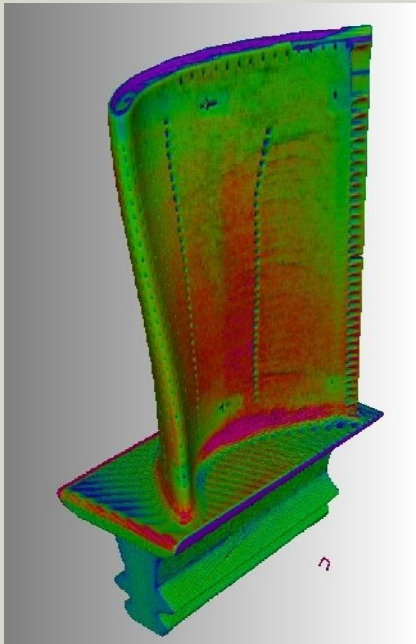
X-ray team at Corporate Technology:

Dr. Matthias Goldammer
Dr. Karsten Schörner
Jürgen Stephan
Christian Watzl
Michael Schrapp (PhD candidate)

…and valuable support by our students:

Andreas Fischer
Andreas Rauscher
Behroz Sikander

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https://intranet.w1.siemens.com/cms/ct/en/main/rtc/set/int-de/