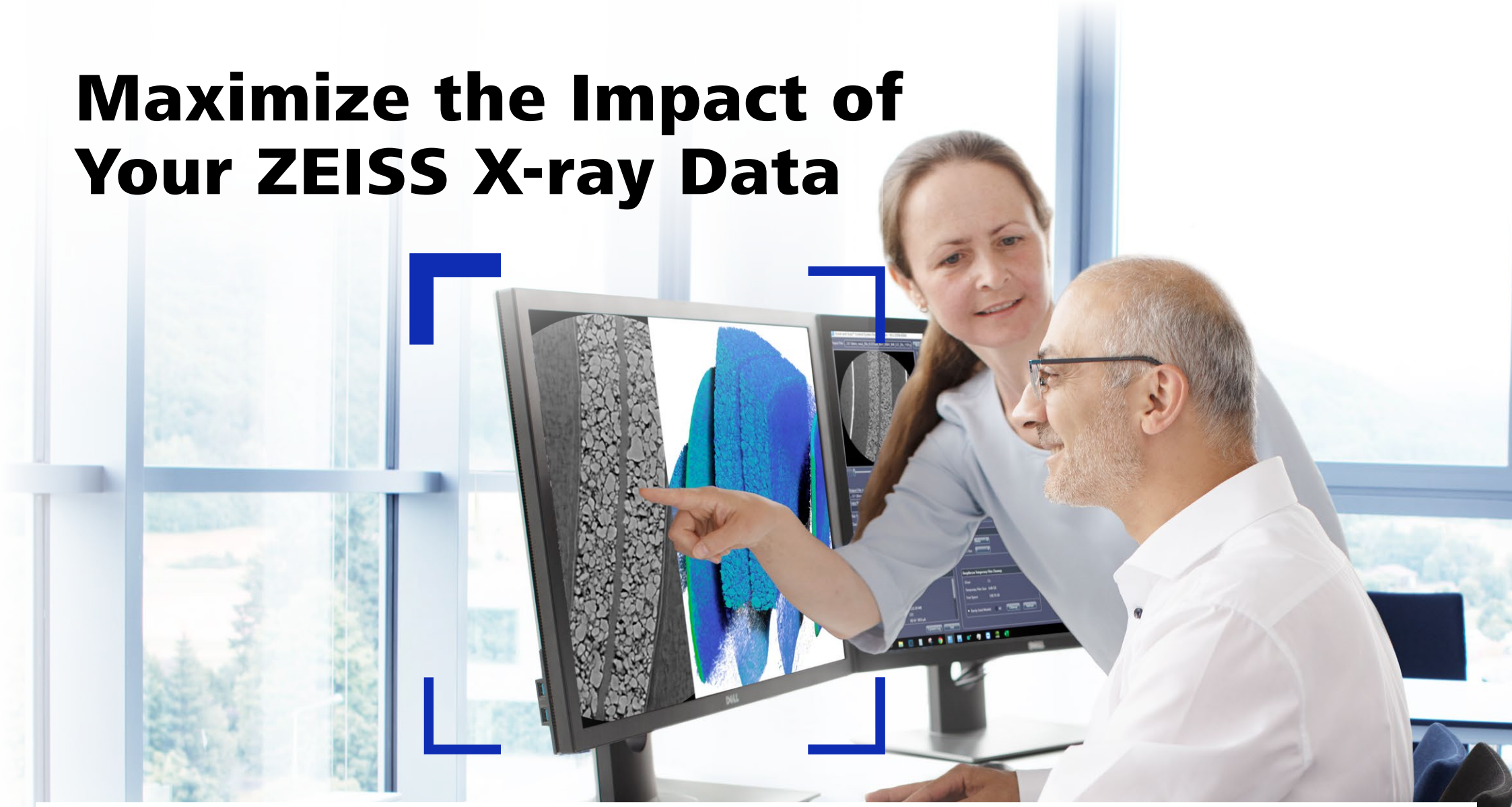
Maximize the Impact of Your ZEISS X-ray Data



ZEISS Advanced Reconstruction Toolbox

Your software for advanced image processing of X-ray data

zeiss.com/art

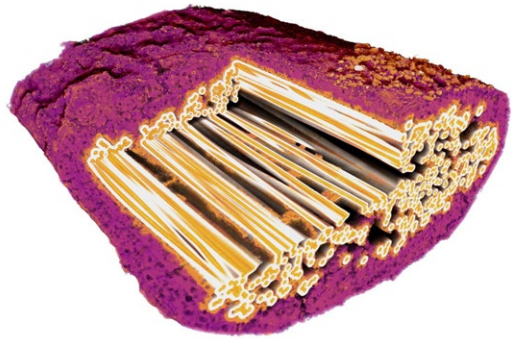
ZEISS

Seeing beyond

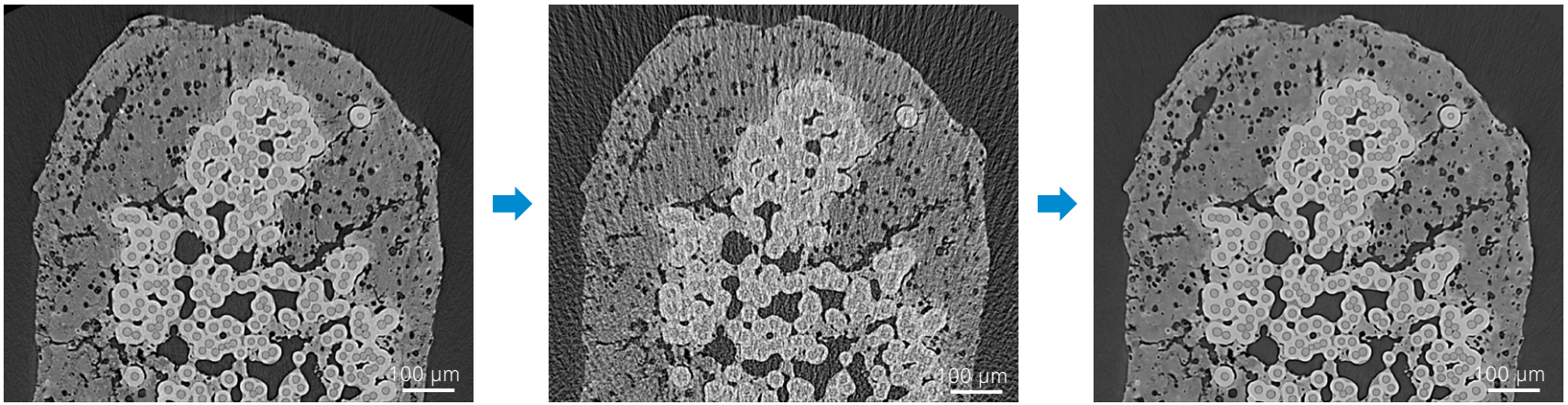
Revolutionize Your 3D X-ray Image Reconstruction.

ZEISS Advanced Reconstruction Toolbox (ART) is an innovative platform through which you can continuously access state-of-the-art reconstruction technologies from ZEISS to enrich your research and increase the return on investment of your 3D X-ray microscope (XRM) and microCT (µCT). These unique offerings leverage artificial intelligence and a deep understanding of both X-ray physics and customer applications to solve some of the hardest imaging challenges in new and innovative ways.

Optional ART modules are workstation- and cloud-based solutions that provide easy access and usability.



Ceramic matrix composite imaged in 3D with ZEISS Xradia 620 Versa XRM. Courtesy of Dr. David Marshall, University of Colorado, Boulder, USA



Standard reconstruction (FDK): Scan time 9 hrs (3001 projections)

Standard reconstruction (FDK): Scan time 53 mins (301 projections)

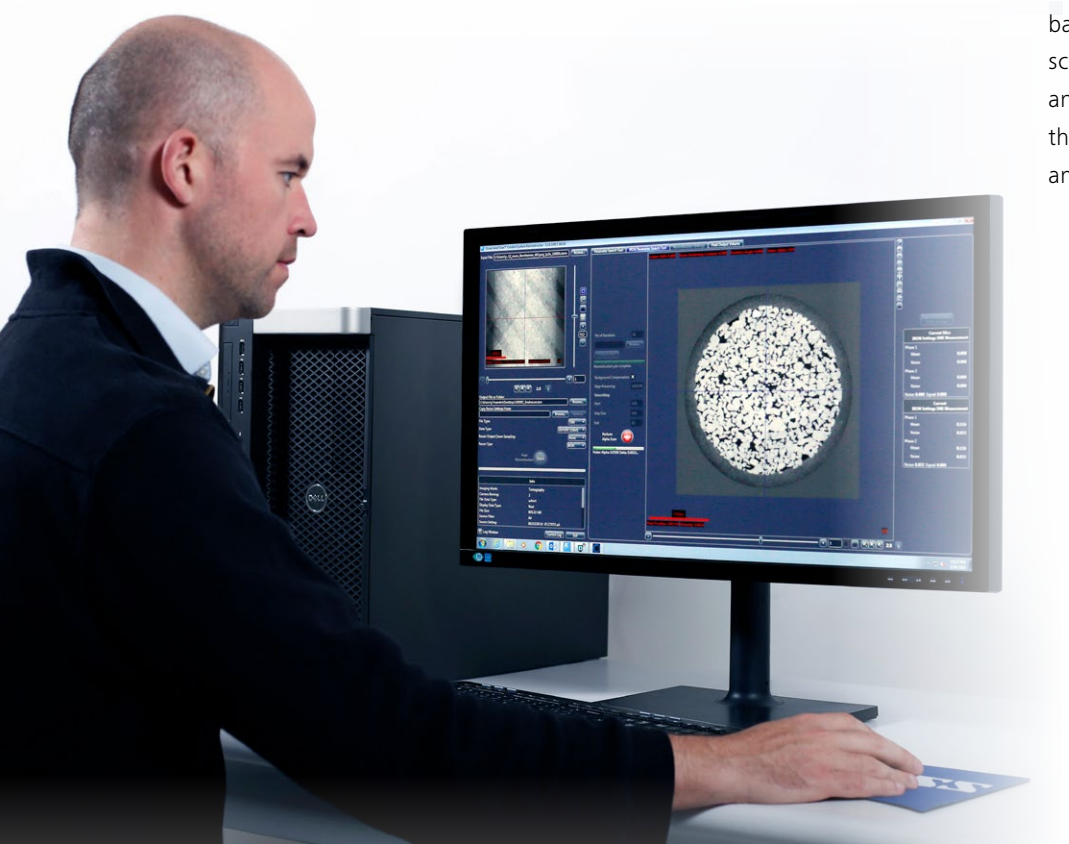
ZEISS DeepRecon Pro: Scan time 53 mins (301 projections)

ZEISS DeepRecon Pro used for throughput improvement for ceramic matrix composite (CMC) sample, achieving 10× throughput improvement without sacrificing image quality. This would allow for much higher temporal resolution for in situ *studies.*

Innovative. Flexible. Ground-breaking.

The Latest Innovations at Your Fingertips

ART for ZEISS XRM and microCT enables you to accelerate productivity in ways never before possible. With continuous delivery of ground-breaking innovation in 3D X-ray microscopy via a variety of image and data processing enhancements, ART meets you where you are. ART is available on a high-performance dedicated workstation, via time-based licensing for project-oriented teams, and in the cloud to provide researchers with ultimate flexibility.



Advanced Image Reconstruction

Image reconstruction technologies enhance 3D X-ray results, enabling you to address:

- Resolution, contrast, and image quality
- Throughput
- Diverse sample types, sizes, and shapes
- Artifact reduction

These capabilities support the study of samples in the fields of materials science, battery research, advanced electronics, life sciences, semiconductors, natural resources, and many more while accommodating the novice to most expert users through an easy-to-use interface.

Expand Your Research Goals with AI

Continued algorithmic innovation in 3D X-ray microscopy reconstruction benefits many different application areas, enabling you to harvest the hidden data in your X-ray acquisitions. These technologies, incorporating artificial intelligence, dramatically reduce your time to result and bring entirely new capabilities to your research, allowing you to build a new understanding of the complex processes taking place. Ultimately, these innovations can improve the statistical significance of your research and experiments and enable you to maximize the impact of the data you collect. Advancements in AI bring new insight across materials and life sciences research and accelerate the pace of development for engineering new materials with enhanced properties.

Your Insight into the Technology Behind It

Computational Imaging

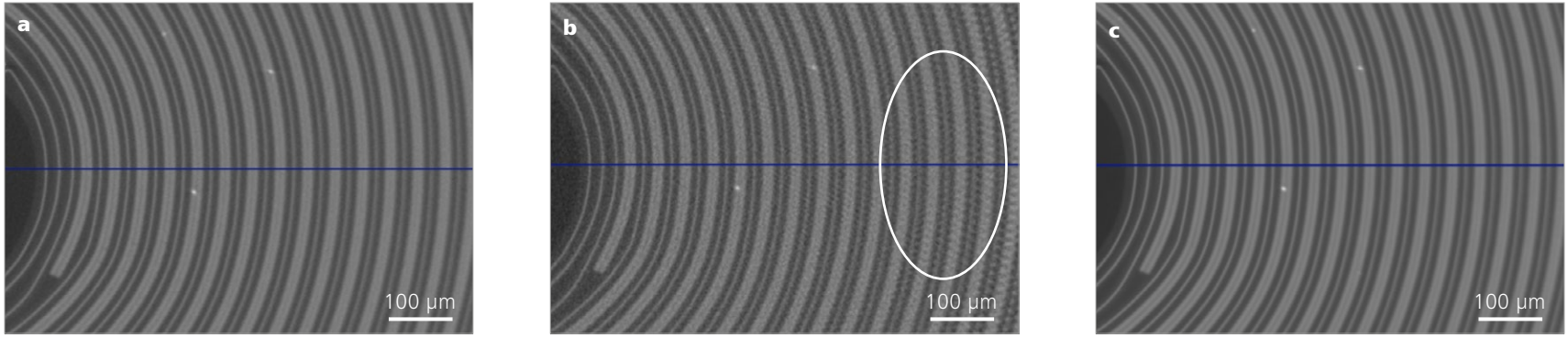
3D X-ray microscopy is a computational imaging technique where a series of many hundreds to thousands of projections are reconstructed and synthesized into a volumetric representation of your sample.

X-ray microscopy presents unique opportunities but also presents significant challenges. Its non-invasive nature allows for the high-resolution imaging of deeply buried materials without causing damage or requiring destructive sample preparation.

However, the relatively low brilliance of laboratory X-ray sources coupled with the relative inefficiency of X-ray detectors create a high degree of noise in detected images, especially at high resolution. On top of this noise issue, images are often subject to sampling or aliasing artifacts that arise from a limited number of projections used for reconstruction. This is particularly an issue when performing high-resolution interior tomographies on large samples.

ART techniques integrate computational imaging at the heart of X-ray microscopy to open up transformative new capabilities.

3D mage of 21700 battery scanned by ZEISS Xradia 620 Versa



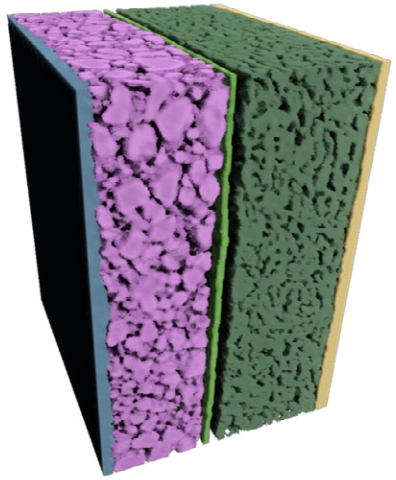
Comparison between standard analytical reconstruction and AI-based reconstruction using DeepRecon Pro on a 21700 cylindrical lithium-ion battery. (a) Standard analytical reconstruction output for an 11-hour scan time. (b) Standard analytical reconstruction output for a 1.4-hour scan time. Significant artifacts appear near the battery perimeter, as highlighted in the white oval. (c) AI-based reconstruction algorithm output for the same 1.4-hour scan, allowing for 8x faster scanning with comparable image quality to the original 11-hour scan.

Your Insight into the Technology Behind It

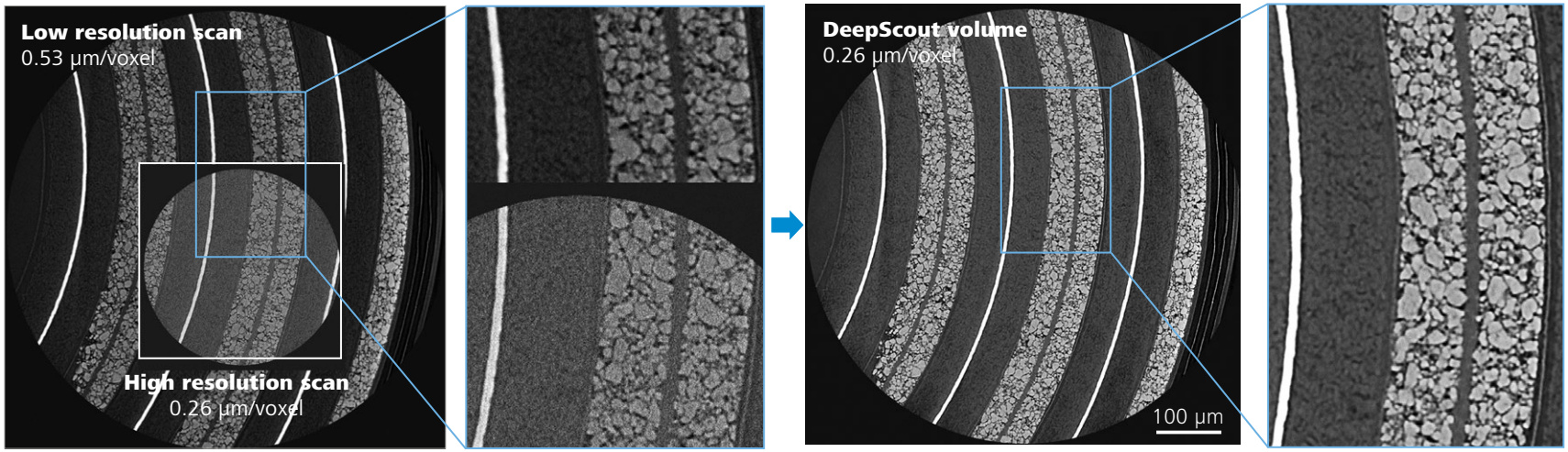
Field of View vs. Resolution

Another challenge inherent to all microstructural imaging techniques, but felt particularly acutely in X-ray imaging, is the relationship between resolution and field of view. Often the high resolution required to image fundamental structural details comes at the expense of the field of view that is representative of sample heterogeneity, leading to uncertainties in the resulting interpretation. Significant progress has been made over the past several years in the development of workflows allowing for the integration of multiscale data via scout and zoom techniques, however, these workflows still do not break the relationship between resolution and field of view.

ART offers a novel X-ray reconstruction capability that couples the multiscale data uniquely available in X-ray microscopy with advanced machine learning to explicitly learn and remove relative image point spread functions (PSF) even on very large field of view data. This allows for high-resolution imaging to be performed without a significant trade-off with respect to field of view.



Segmented 3D rendering of pouch cell battery scanned by ZEISS Xradia 620 Versa. From left to right: cathode current collector (blue), cathode particles (pink), polymer separator membrane (light green), graphite anode particles (dark green), anode current collector (gold).



Pouch cell battery: initially capture at a low-resolution sample scan, scout to a smaller region to perform a high-resolution scan. Train the AI network on your data, and then apply to the low-resolution data to achieve high resolution across a larger field of view.

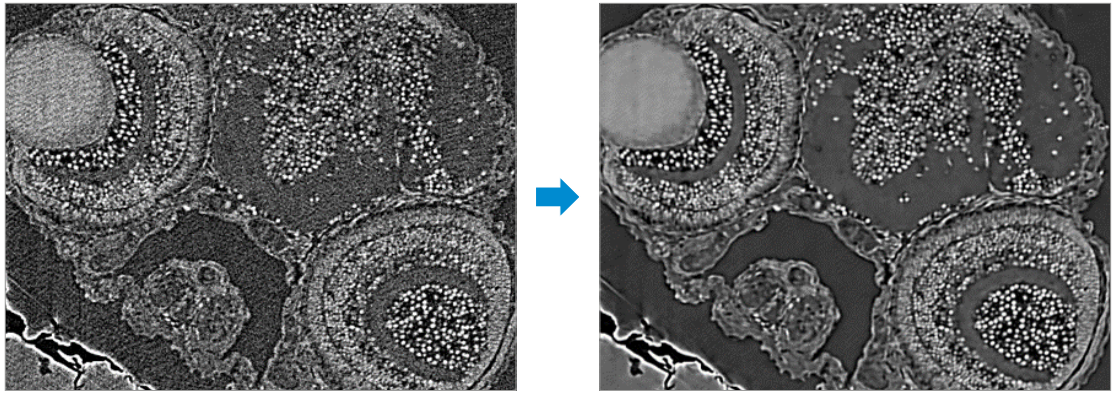
Expand Your Possibilities

DeepRecon Pro

ZEISS DeepRecon Pro is an innovative AI-based technology that brings superior throughput and image quality benefits across a wide range of applications. It uniquely harvests the hidden opportunities in big data generated by your XRM or microCT and provides significant AI-driven speed or image quality improvement.

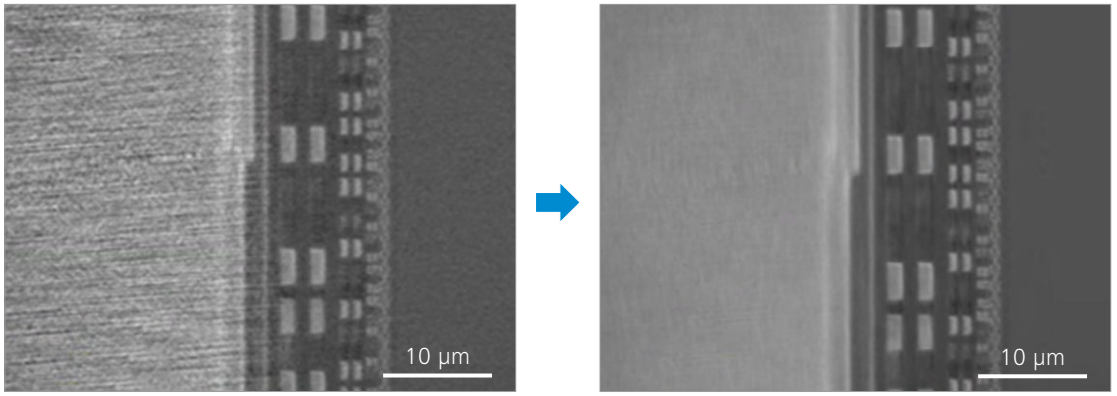
DeepRecon Pro is applicable to both unique samples as well as semi-repetitive and repetitive workflows. Users can self-train new machine-learning network models with an extremely easy-to-use interface. The one-click workflow of DeepRecon Pro eliminates the need for a machine learning expert and can be seamlessly operated by even novice users.

DeepRecon Pro is offered as part of the AI Supercharger and Recon packages for the Advanced Reconstruction Toolbox and is also available via the cloud.



Standard reconstruction *ZEISS DeepRecon Pro*

In this submicron image of a zebrafish showing standard FDK reconstruction, above left, the DeepRecon Pro image, above right, shows significant improvement with less noise and more features. Courtesy Prof. Dr. Bert Müller, University of Basel, Switzerland



Standard reconstruction *ZEISS DeepRecon Pro*

fcBGA Flip Chip sample imaged with ZEISS Xradia Ultra. Standard FBP reconstruction (above left) 64 nm/voxel scan: 1000 projections at 18 hours.
Compare this to DeepRecon Pro reconstruction (above right) using 250 projections in a 4.5-hour scan resulting in better image quality and 4X throughput improvement.

Expand Your Possibilities

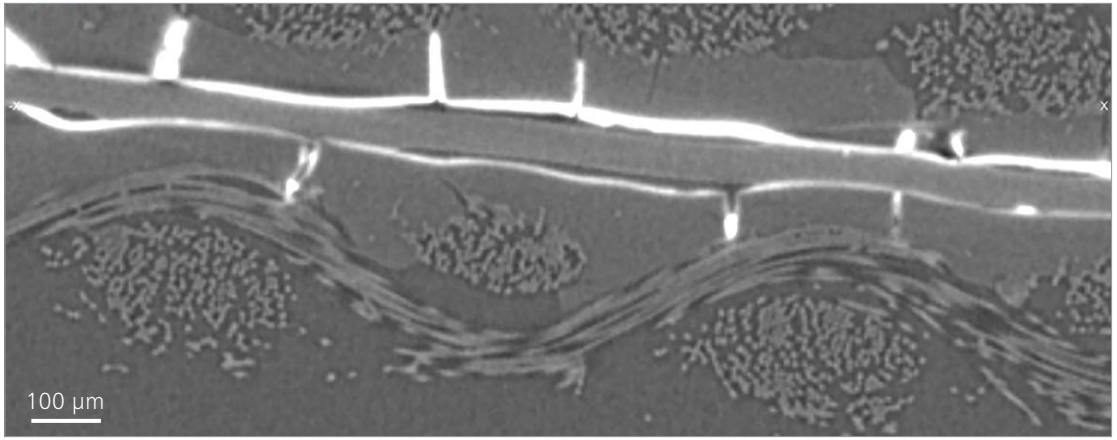
DeepScout

ZEISS DeepScout uses high-resolution 3D microscopy datasets as training data for lower resolution, larger field of view datasets and upscales the larger volume data employing a neural network model. Leveraging the unique XRM Scout-and-Zoom capability, DeepScout generates multiscale, spatially registered datasets to train neural networks, providing richer information at higher resolution, including for interior tomographies for large samples.

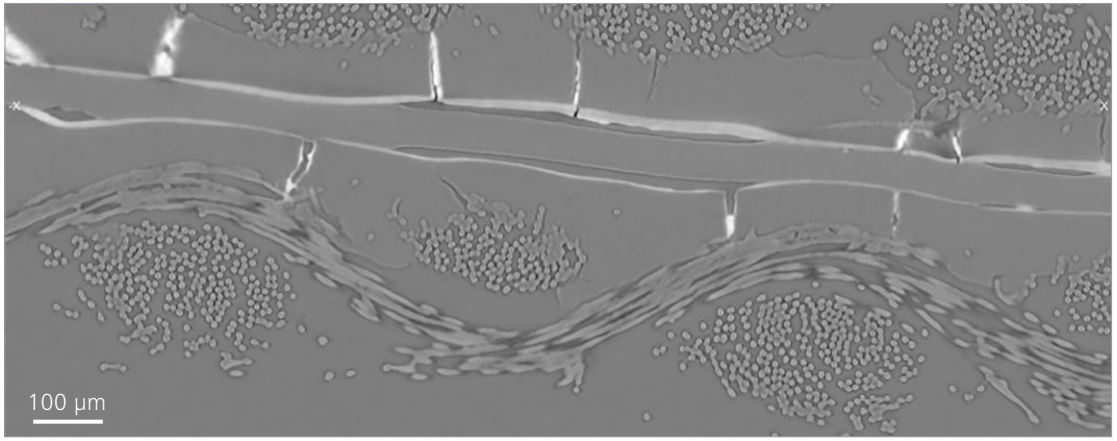
These new capabilities, fueled by deep learning, mitigate the traditional trade-off between field of view and resolution. This allows you to identify spatially unconnected regions for further analysis without the need to image the entire sample in high resolution.

After training your network, feed your large volume overview scan through the Deep-Scout reconstruction algorithm, and obtain resolution that approaches the resolution of a Zoom scan, but over a much larger field of view.

DeepScout is offered as part of the AI Supercharger package for the Advanced Reconstruction Toolbox and is also available via the cloud.



Polymer electrolyte fuel cell (PEFC) membrane electrode assembly imaged without ZEISS DeepScout.



ZEISS DeepScout: Acquire high resolution data across entire sample image for a clear view of critical microstructural features that influence water formation and fuel cell performance.

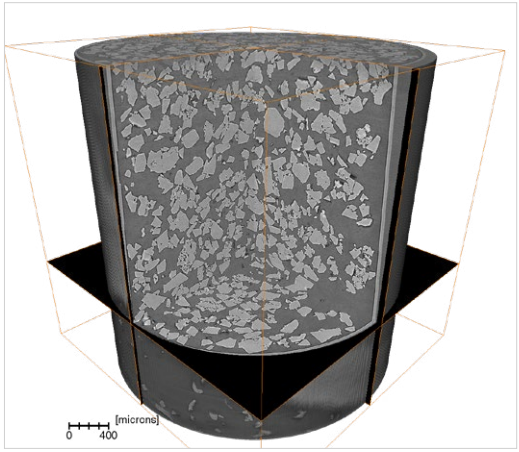
Expand Your Possibilities

PhaseEvolve

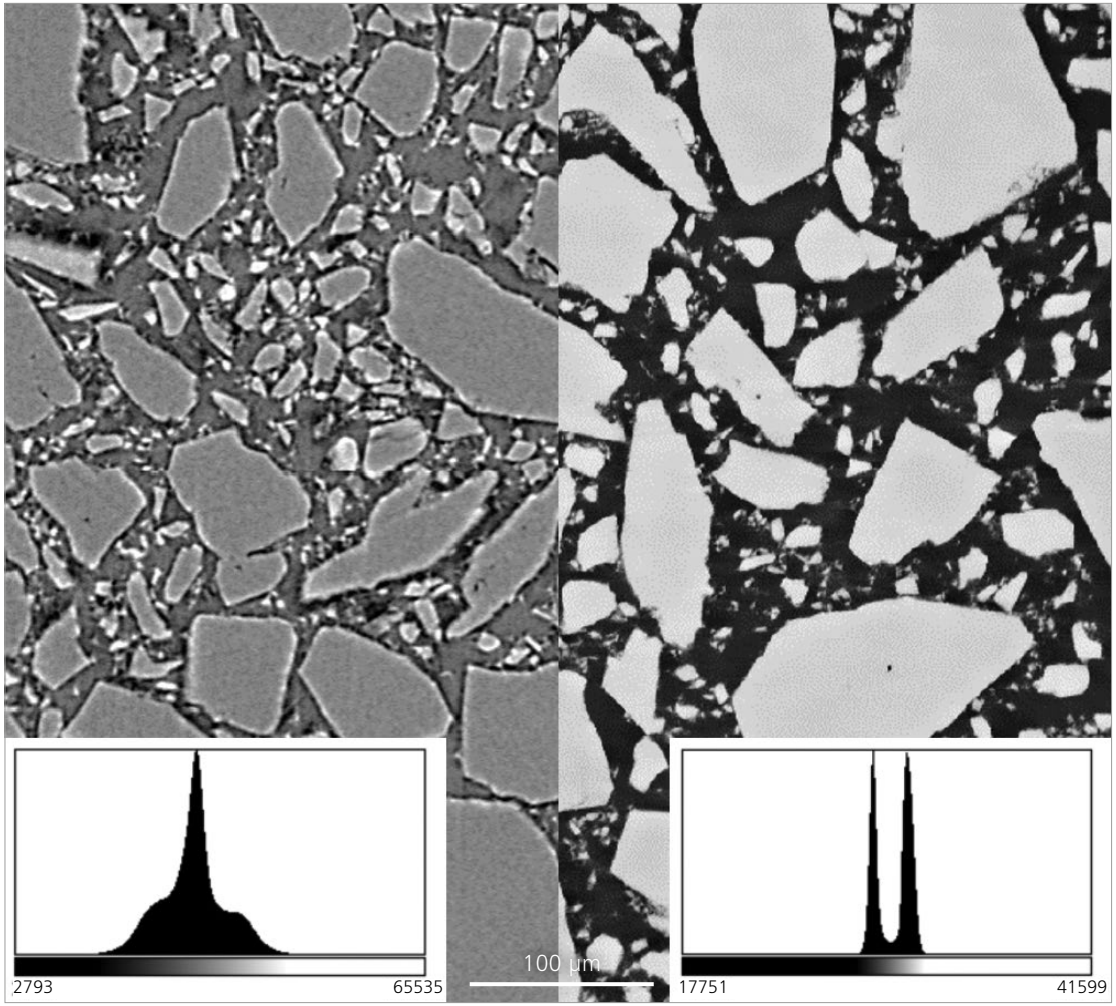
ZEISS PhaseEvolve is a patented* post-processing reconstruction algorithm that enhances the image contrast by revealing material contrast uniquely inherent to X-ray microscopy, which can often be obscured by phase effects in low-medium density samples or high-resolution datasets. Perform more accurate quantitative analysis with improved contrast and segmentation of your results.

PhaseEvolve is offered as part of the Artifact Reduction package for the Advanced Reconstruction Toolbox and is also available via the cloud.

** Patent US11645792B2*



Lactose carrier powder scanned with ZEISS Xradia 620 Versa to observe particles nondestructively in 3D.



Comparing standard FDK reconstruction before and after applying PhaseEvolve: a pharmaceutical sample consisting of large lactose carrier particles and smaller (< 1 µm) active pharmaceutical ingredient (API) particles. The image on the left is without PhaseEvolve processing; image on the right is with PhaseEvolve. Histograms show the distribution of intensities in the images. Left, all phases are convoluted, making it difficult to segment the image. Right, the histogram shows well-differentiated phases with PhaseEvolve, as seen in the two distinct peaks.

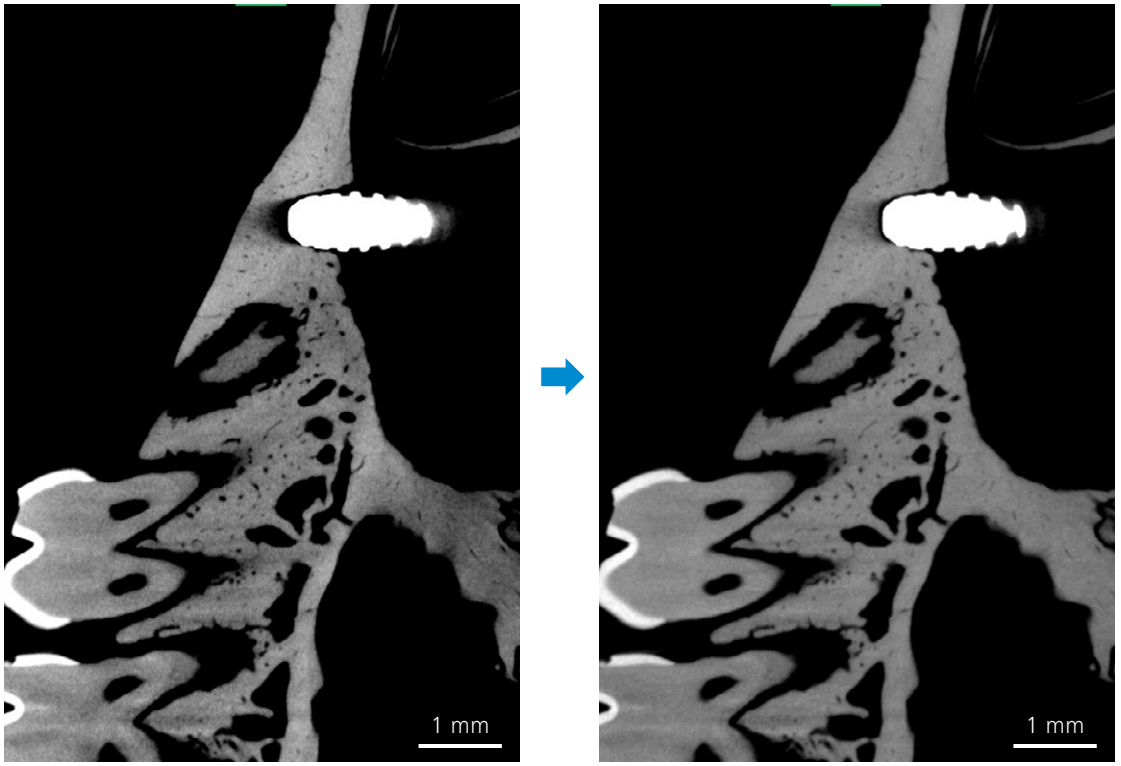
Expand Your Possibilities

Materials Aware Reconstruction Solution (MARS)

ZEISS MARS is a reconstruction algorithm that is aware of the constituents within a reconstruction. A challenge in X-ray reconstruction in a lab setting is that imaging with a polychromatic source creates different X-ray energies to generate a phenomenon called beam hardening. This effect is particularly challenging when your material is very dense and embedded in a relatively less dense material. The MARS advanced correction algorithm informs the system how to compensate for the effect of extreme beam hardening in the regions between very dense objects.

This is important in applications like biomaterials, where you might be looking at implants next to bone or tissue. Or electronics where extremely dense solder balls appear next to other less dense materials on a printed circuit board, generating strong artifacts. MARS reconstructs your images to compensate for these effects.

Materials Aware Reconstruction Solution is part of the Artifact Reduction package of ART.



MARS artifact reduction around implant into bones. Metal implant in bone without MARS (left) casts artifacts directly around the implant, and with MARS (right) demonstrates little to no artifact around the implant.

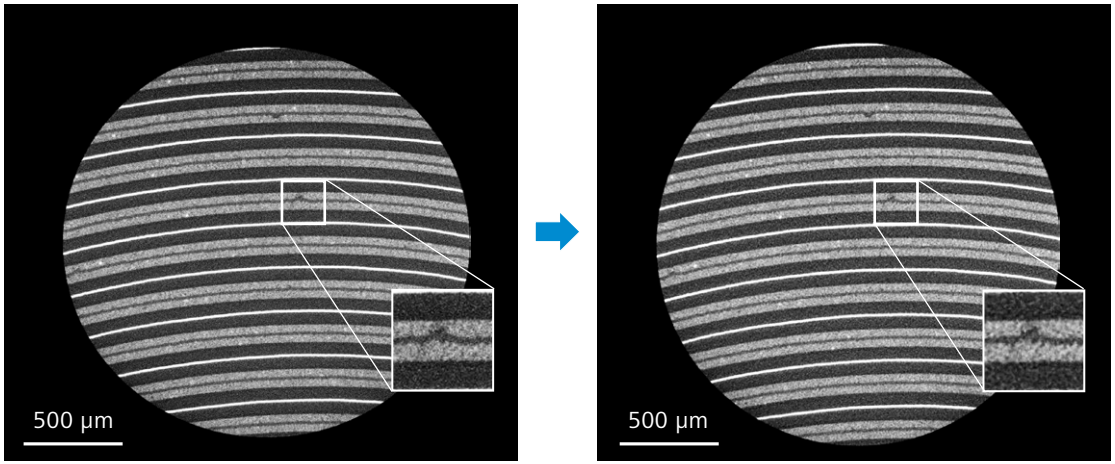
Expand Your Possibilities

OptiRecon

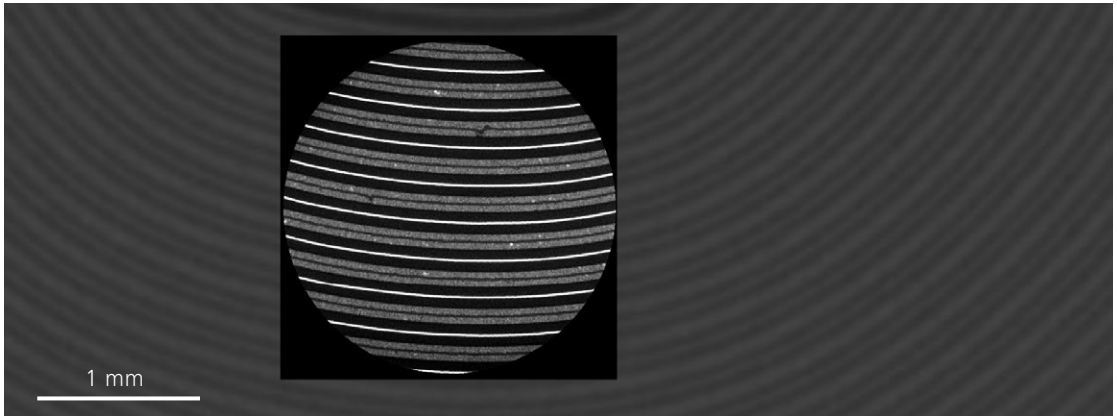
ZEISS OptiRecon is fast and efficient algorithm-based technology that delivers iterative reconstruction from your desktop, allowing you to achieve up to 4× faster scan times or enhanced image quality with equivalent throughput.

OptiRecon is an economical solution offering superior image quality or faster throughput on a broad class of samples.

OptiRecon bonds with DeepRecon to create the Recon package of ART.

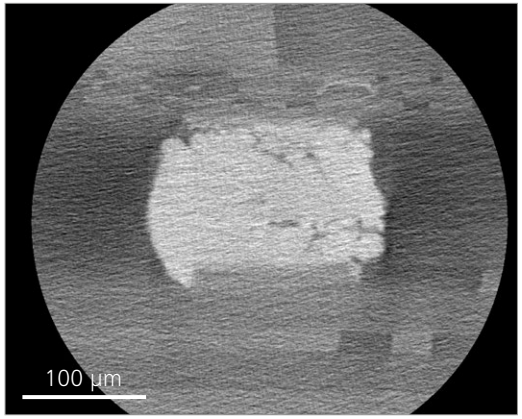


18650 battery: Standard reconstruction – 6000 projections vs. OptiRecon – 1500 projections. 4X throughput improvement with equivalent image quality.

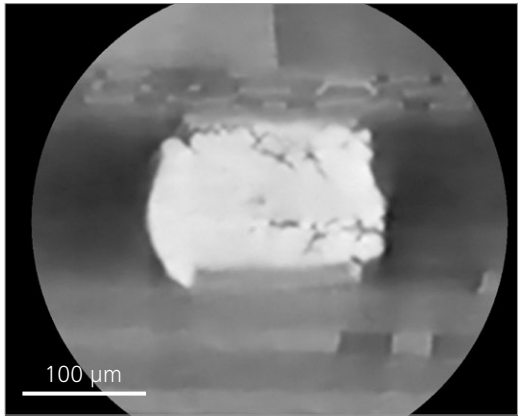


18650 Li ion battery, interesting for its applications in the automotive industry and mobile consumer devices. Internal tomography reveals detail of the electrode level structure, including aging effects, foreign particles, and cracks. Imaged with ZEISS Xradia 620 Versa.

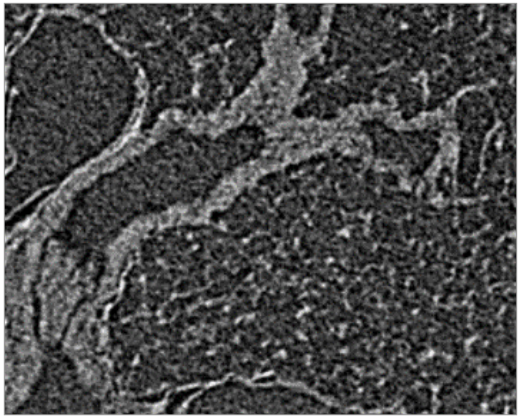
ZEISS DeepRecon Pro at Work



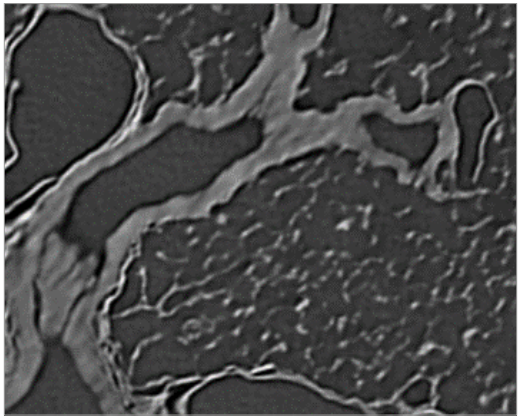
Imaging of A12 bump for failure analysis with standard FDK generates noise that obscures the severity of the internal defects of this sample.



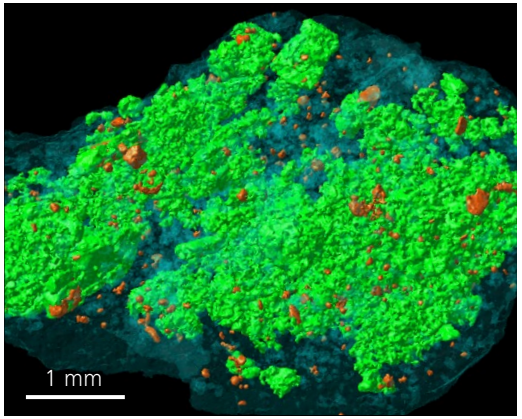
DeepRecon Pro enables high quality datasets for true visualization of the internal defects of this solder bump, without the noise shown in the standard FDK reconstruction.



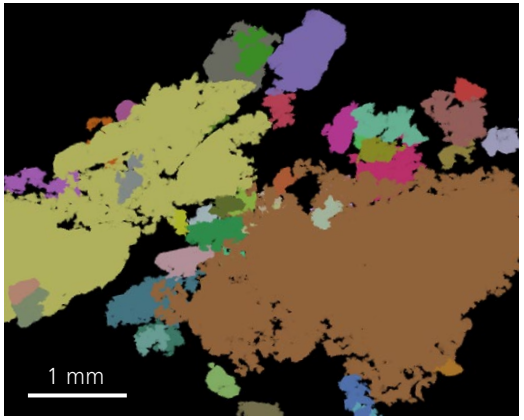
Mouse lung imaged with Xradia Versa. Sample is iodine stained and captured with 3001 projections. Reconstruction done using traditional FDK.



Reconstruction done using DeepRecon Pro, showing improved image quality compared to FDK.



Winchcombe meteorite. Segmentation following deep learning-assisted reconstruction with DeepRecon Pro allowed clasts (green) and matrix (pale blue) to be separated. Sulfide and oxide minerals (orange-red) were also characterized using 3D automated mineralogy with ZEISS Mineralogic 3D.

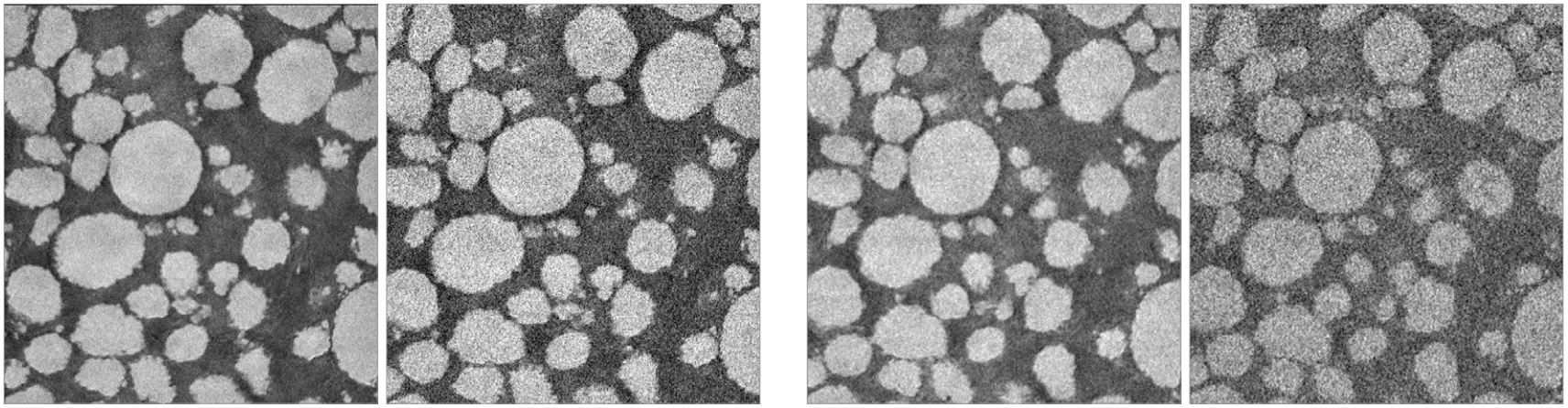


Winchcombe meteorite. DeepRecon Pro enhances the ability to distinguish similar mineral phases, enabling size, distribution, and shape analysis of clasts that give insights into collisional processes happening on the initial parental body from which the meteorite originated.

ZEISS DeepRecon Pro Ultra at Work

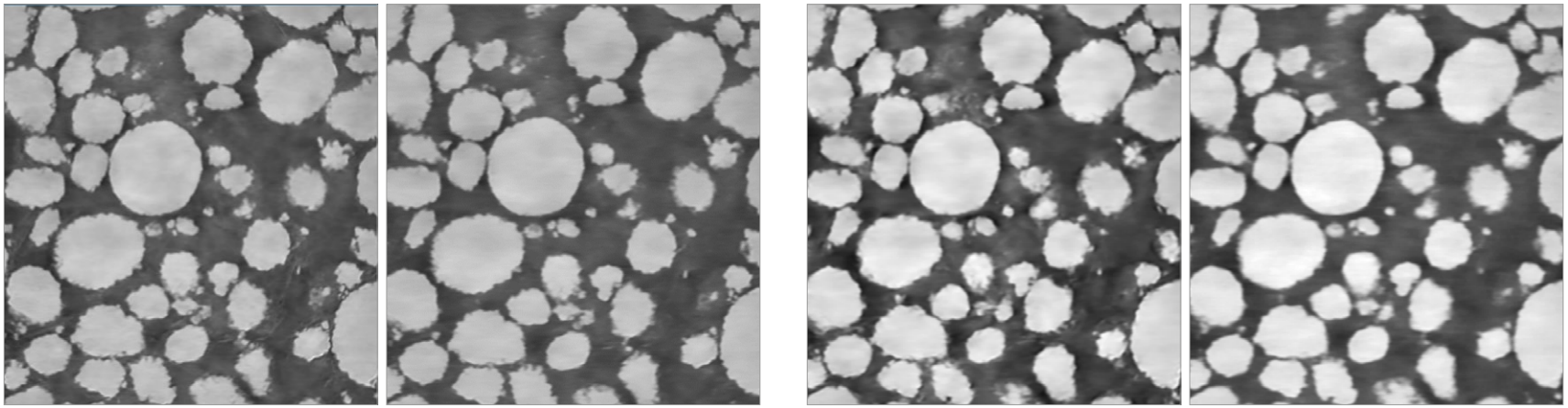
Standard

15 hours; 18 minutes | 2 hours; 39 minutes | 2 hours; 5 minutes | 16 minutes



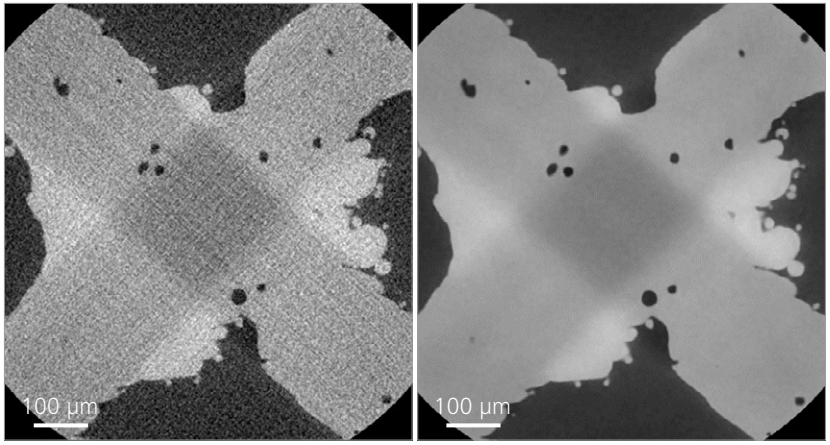
DeepRecon Pro Ultra

15 hours; 18 minutes | 2 hours; 39 minutes | 2 hours; 5 minutes | 16 minutes

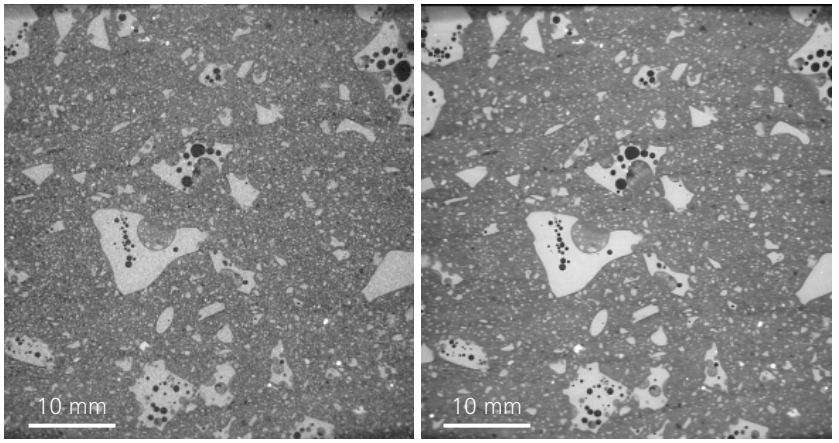


Battery cathode layer scanned with ZEISS Xradia Ultra, nanoscale XRM, comparing standard FDK and DeepRecon Pro for both image quality and throughput (time to information).
Bin 1, at 64 nm voxel size (left two columns), shows DeepRecon Pro is 6X faster, and Bin 2, at 128 nm voxel size (right two columns), is 8X faster, bringing an Ultra XRM into new avenues of research. Field of view is 65 µm in each frame.
Each reconstruction model has been "self-trained," using its own data, as part of the Image Quality Improvement DeepRecon Pro workflow. No prior data or scan has been used for model training.

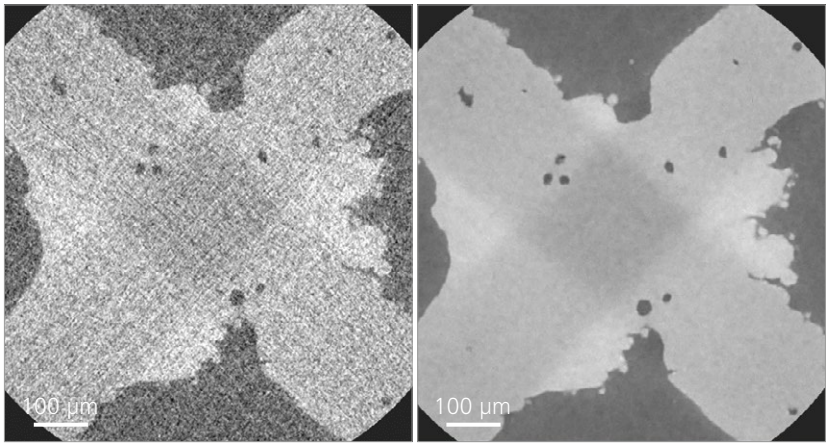
ZEISS DeepRecon Pro at Work



Standard reconstruction: 1601 projections *DeepRecon Pro: 1601 projections*

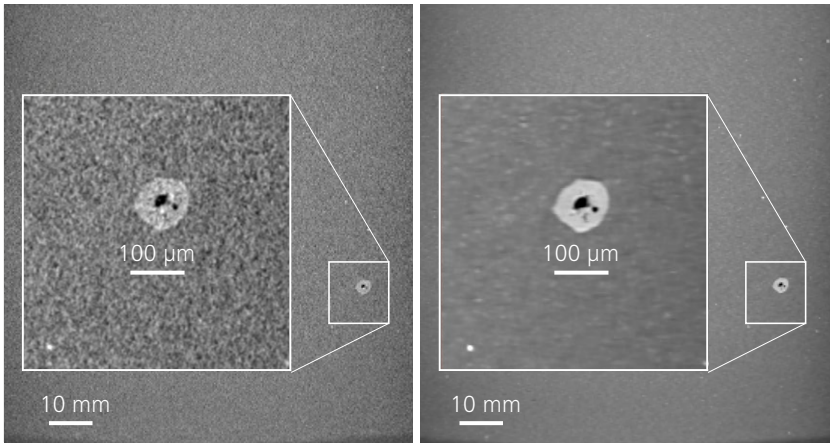


Blended Portland cement with residual blast furnace slag particles. Comparison between standard FDK (left) and DeepRecon Pro (right) demonstrates de-noising and image quality improvement in Deep-Recon Pro data.



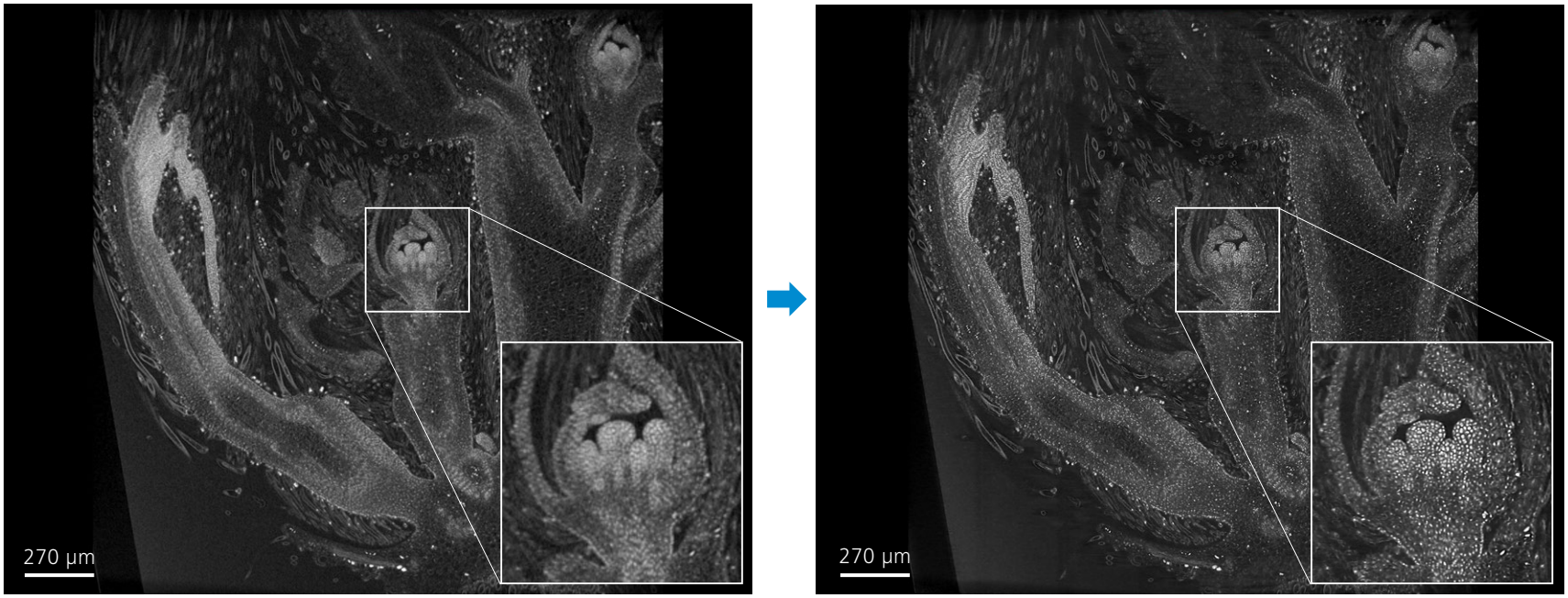
Standard reconstruction: 401 projections *DeepRecon Pro: 401 projections*

Additively manufactured Inconel lattice. ART with DeepRecon Pro demonstrates better image quality at same number of projections, and also at 4X throughput improvement. Sample courtesy of Kavan Hazeli, Mechanical and Aerospace Engineering, The University of Alabama, Huntsville, AB USA.



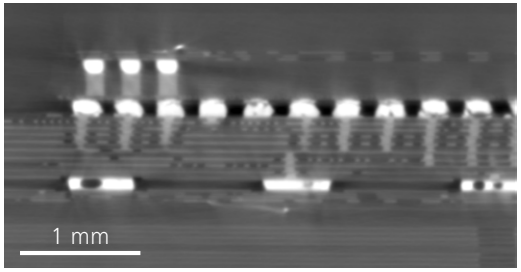
Geopolymer with an encapsulated particle of Fe-rich sludge waste embedded in an otherwise featureless geopolymer matrix. It was difficult not only to identify these grains but also to determine a robust shape analysis using FDK reconstruction alone, but much smaller Fe-rich grains can be observed in DeepRecon Pro data, which would have otherwise been obscured by noise, within the "featureless" geopolymer matrix.

ZEISS DeepScout at Work

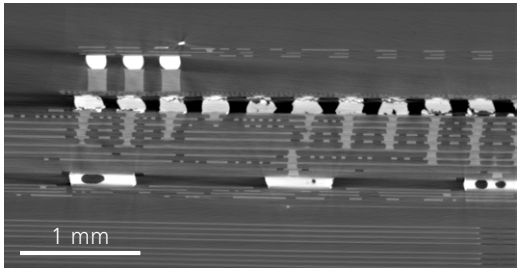


Soybean flower. Left, imaged with standard FDK. Right, imaged with DeepScout. Reduced noise and higher resolution at field of view reveal additional cellular structure.
Sample courtesy of Keith Duncan, Donald Danforth Plant Science Center, Missouri, USA

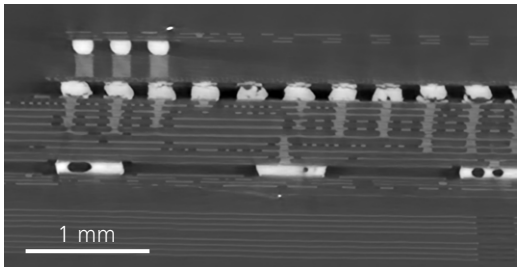
ZEISS DeepScout at Work



Cropped large field of view scan, 10 µm/voxel

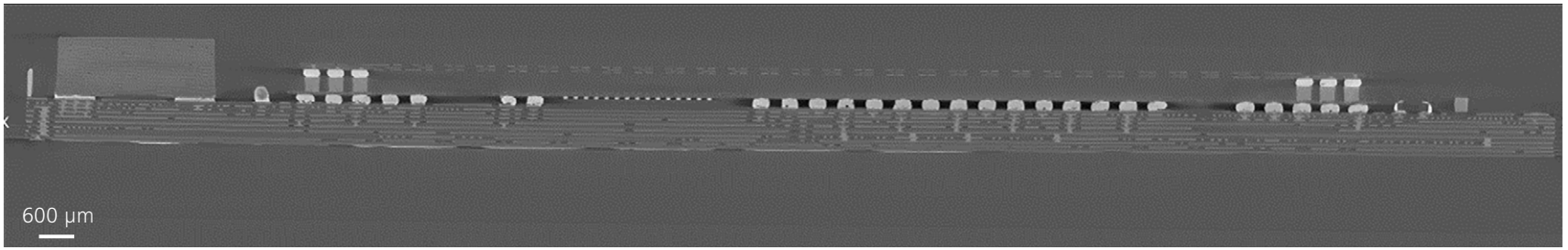


High resolution scan, 2.1 µm/voxel

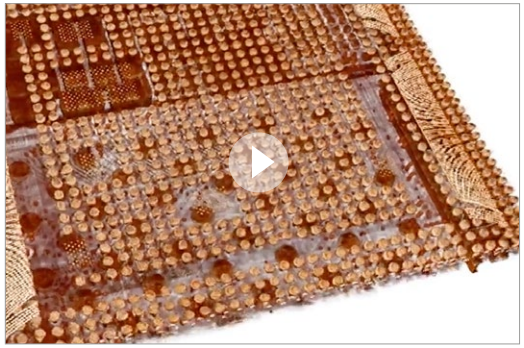


ZEISS DeepScout restored volume, 2.1 µm/voxel

ZEISS DeepScout enables high resolution everywhere in a large FOV volume with no need for numerous high resolution scans. The DeepScout example shown above took only 3 hours in data acquisition, achieving a large and high resolution volume that would require at least 81 hours with standard data acquisition. The DeepScout images clearly show fatigue solder cracks in a commercial A12 smartphone control board, with the image quality comparable to the actual high-resolution scan.

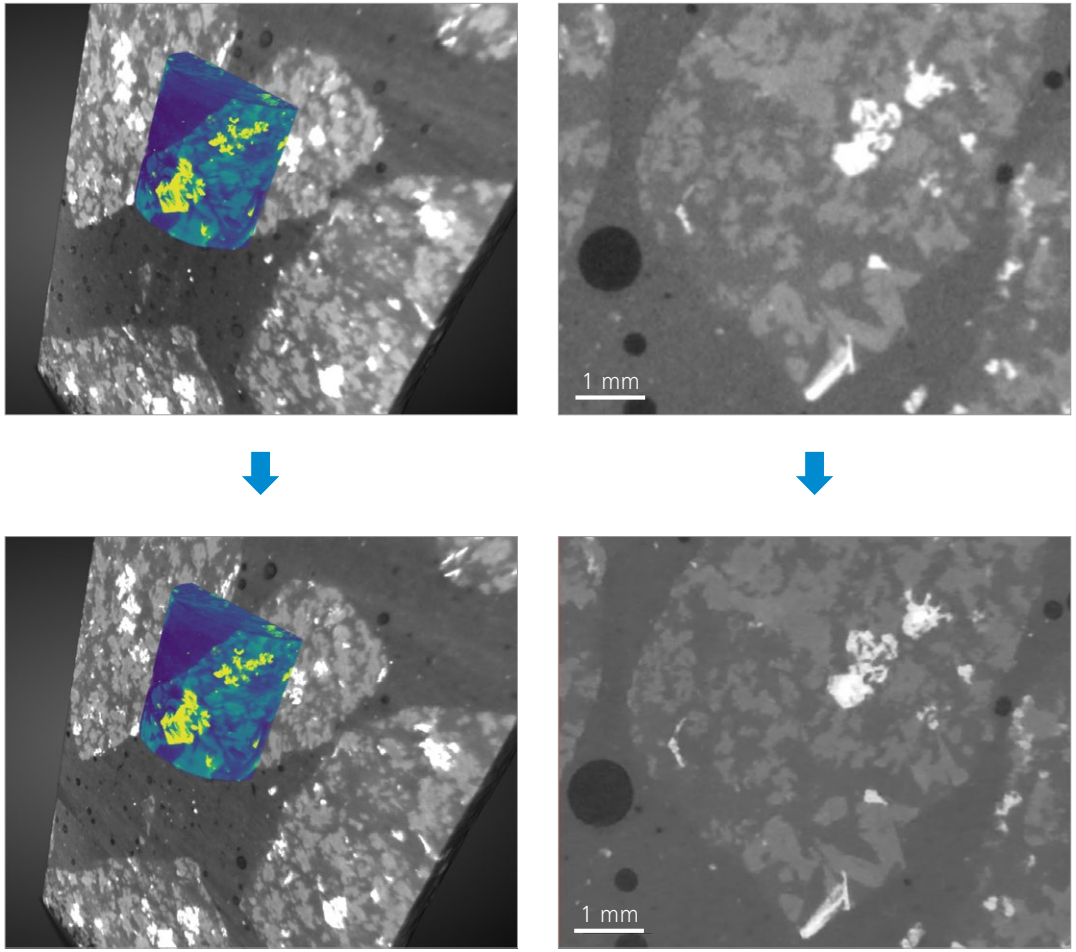


The single full field of view DeepScout scan was generated in 1.6 hours. A single high resolution scan took 2.5 hours. It would require 27 high-resolution scans, or 67.5 hours, to achieve the same volume of data as the DeepScout scan. This provides the ability to drastically reduce the time taken to identify critical regions of interest in large samples for future study.

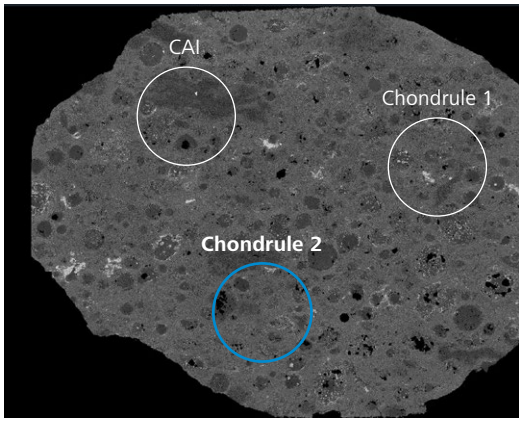


Advanced Reconstruction Toolbox (ART) leverages game-changing artificial intelligence (AI) for reconstruction. ZEISS DeepScout uses high-resolution 3D microscopy datasets as training data for lower resolution, larger field-of-view datasets, and upscales the larger volume data using a trained model. This A12 chip package measures approximately 20 mm wide.

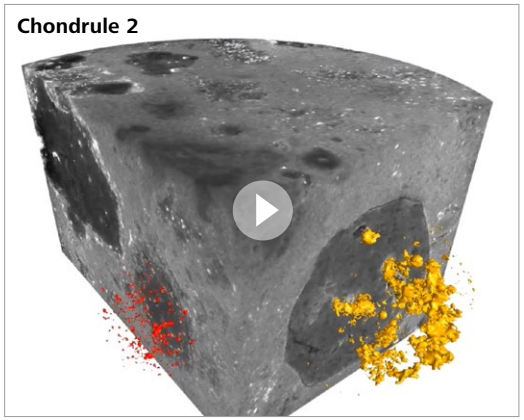
ZEISS DeepScout at Work



Dolerite concrete. Upscaling of internal 4× region of interest (ROI) 5 µm voxel size scan data to larger field of view 0.4x 28 µm voxel size scan. Internal tomography of targeted ROI scan shown in bright colors at left. Using DeepScout improves the contrast between different constituents, the visibility and identification of small grains within the matrix, and the outline and features within high density grains.

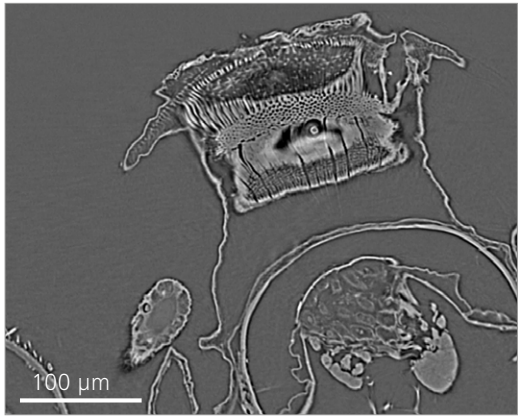


Allende meteorite: 3D sub-sample locations



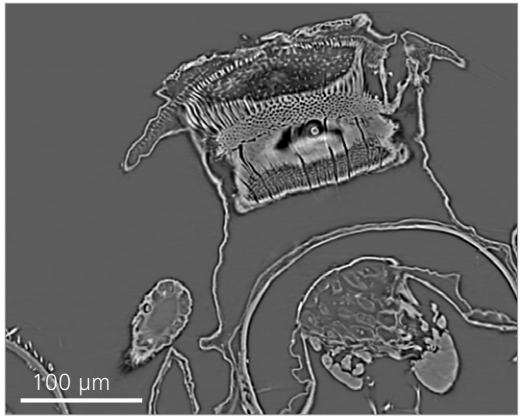
5 mm core of the Allende meteorite. Sample has been scanned using ZEISS Xradia 620 Versa XRM at a 5 µm voxel size and upscaled to a 2 µm voxel resolution using deep learning-powered DeepScout. Individual mineral elements have been segmented using ORS Dragonfly Pro software.

ZEISS PhaseEvolve at Work



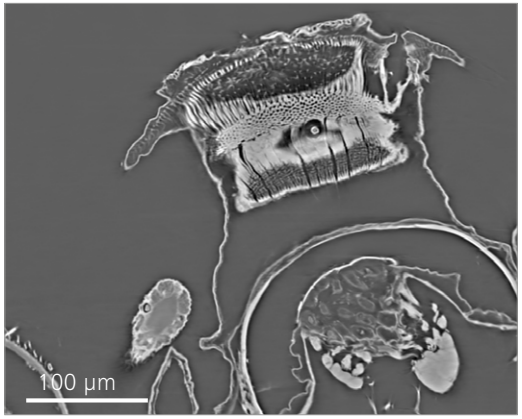
Standard reconstruction: 24 hours

Deformable suction cup organ of the Dipteran fly Hapalothrix lugubris, reconstructed with standard FDK.



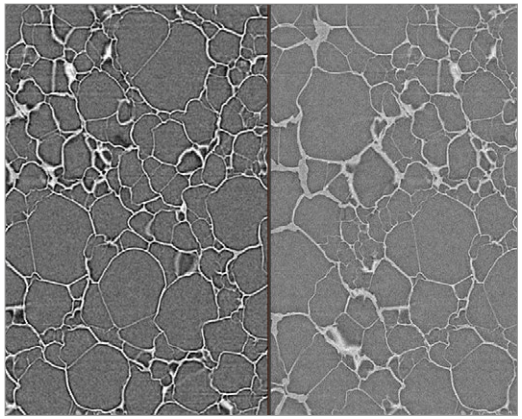
DeepRecon Pro: 24 hours

Using DeepRecon Pro for visualization, image quality is greatly enhanced and simultaneously delivers reduced noise.

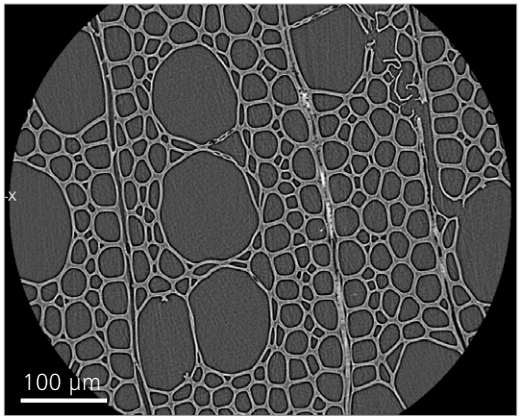


PhaseEvolve + DeepRecon Pro: 24 hours

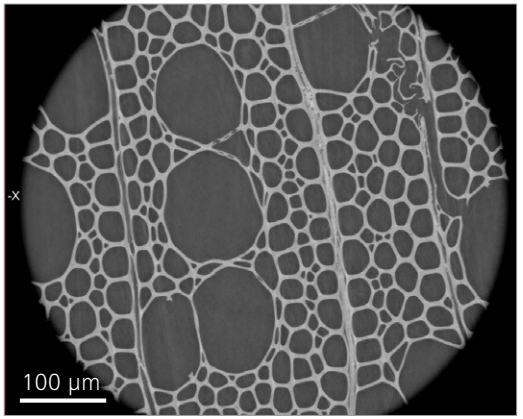
By combining with PhaseEvolve, contrast across the entire structure is maintained, facilitating segmentation to determine structural functionality of the system.



Low absorbing hydrogel sample imaged at high resolution of 0.3 µm/voxel. Phase contrast brings out the walls of the hydrogel, but it is challenging to gauge the wall thickness accurately. Data processed with PhaseEvolve (right) shows a more accurate representation of the actual wall thickness. Field of view is 300 µm.

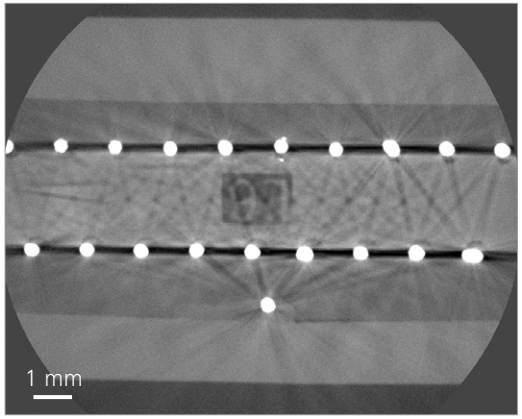


Low absorbing poplar wood requiring phase contrast imaging to resolve smaller microstructural features. 2D reconstructed slice shows regions of wood cell walls with grey values similar to the air in the center of the cells. Field of view is 600 µm.

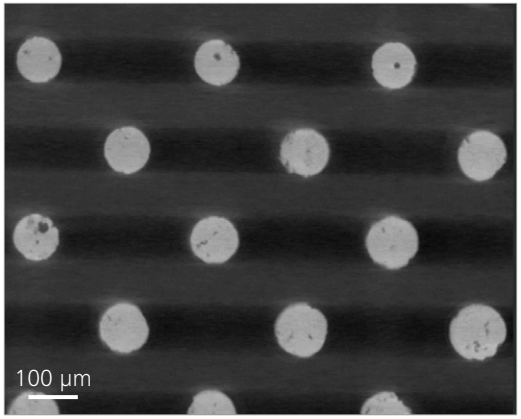


Improvements after PhaseEvolve processing now enable easy segmentation and view of wood cell walls.

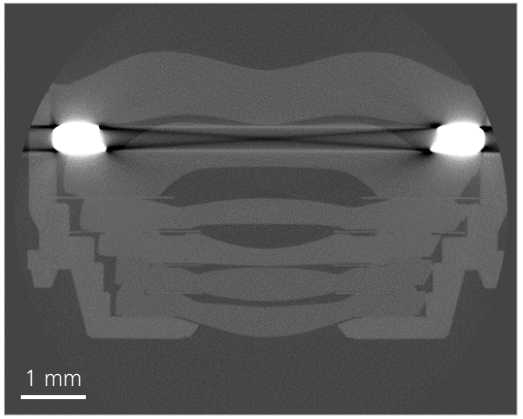
ZEISS Materials Aware Reconstruction Solution at Work



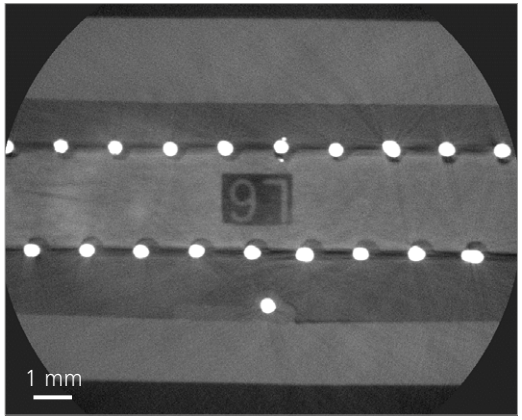
HDMI connector imaged at 160 kV HE 18, reconstruction without MARS shows streaks, dark bands. Field of view is 14 mm.



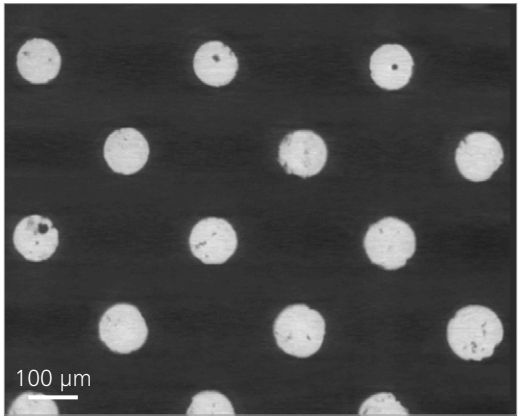
2.5D Interposer semiconductor package imaged at 0.7 µm/voxel using at 80 kV LE2 without MARS shows metal streaking.



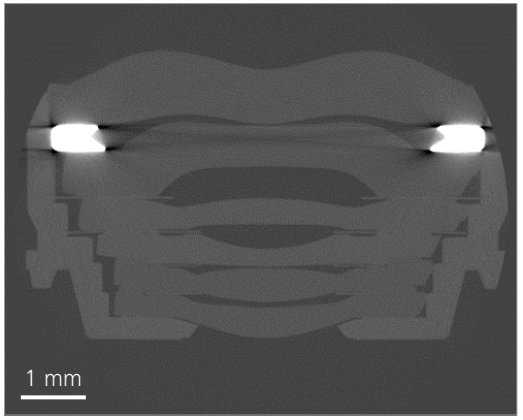
Smartphone camera lens optics imaged at 7.5 µm/voxel using 150 kV HE2 shows metal artifacts.



With MARS: important data is easier to discern without artifacts. Additionally, less filtering equals faster imaging.

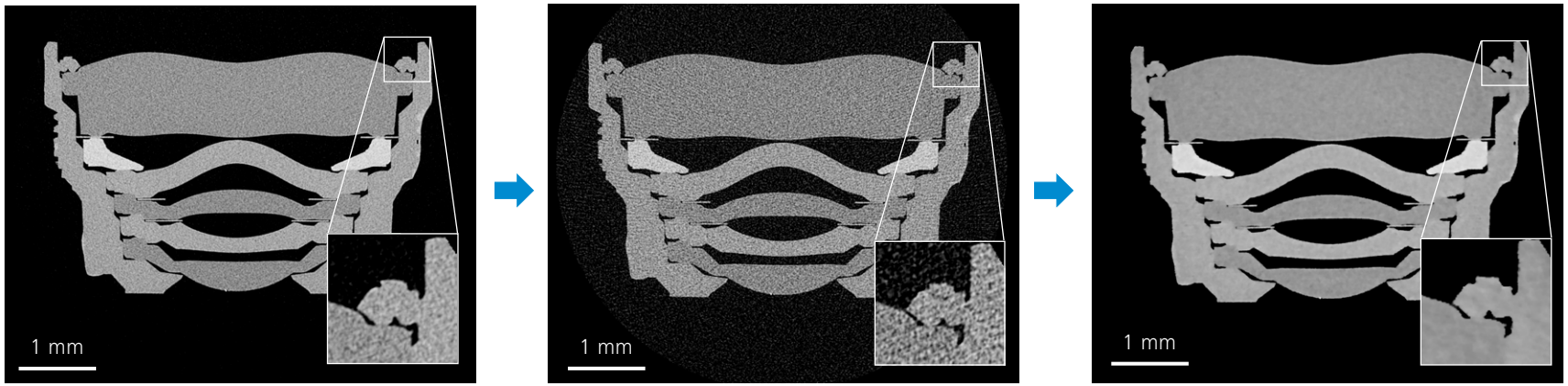


MARS reduces artifacts.



Reduced artifacts with MARS correction.

ZEISS OptiRecon at Work

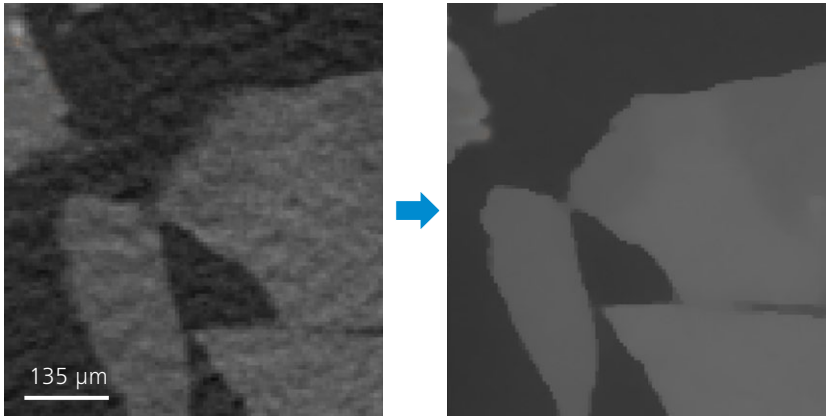


Standard reconstruction: Scan time 90 minutes (1200 projections)

Standard reconstruction: Scan time 22 minutes (300 projections)

OptiRecon: Scan time 22 minutes (300 projections)

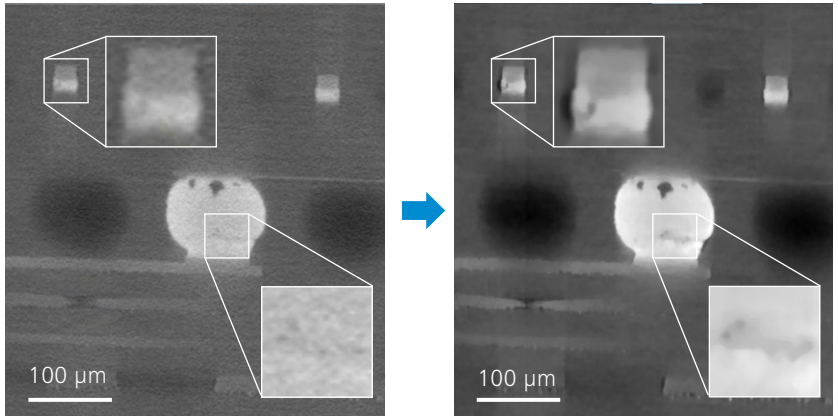
Observe the performance of ZEISS OptiRecon in a workflow performed on an electronics sample. Analyze integration issues in a smart phone camera lens, 4× faster with less noise than FDK using ZEISS OptiRecon.



FDK reconstruction: 400 projections

OptiRecon: 400 projections

Virtual slices extracted from FDK and iterative reconstruction of a mining sample.



FDK reconstruction: 8 hours (801 projections)

OptiRecon: 4 hours (400 projections)

3D XRM virtual cross-section images of a 2.5D package from ZEISS Xradia Versa 3D X-ray microscope. ZEISS OptiRecon reconstruction demonstrates 2X faster scans with excellent image quality of solder defects and cracks.

Architecture That Leads to Flexibility & Accessibility

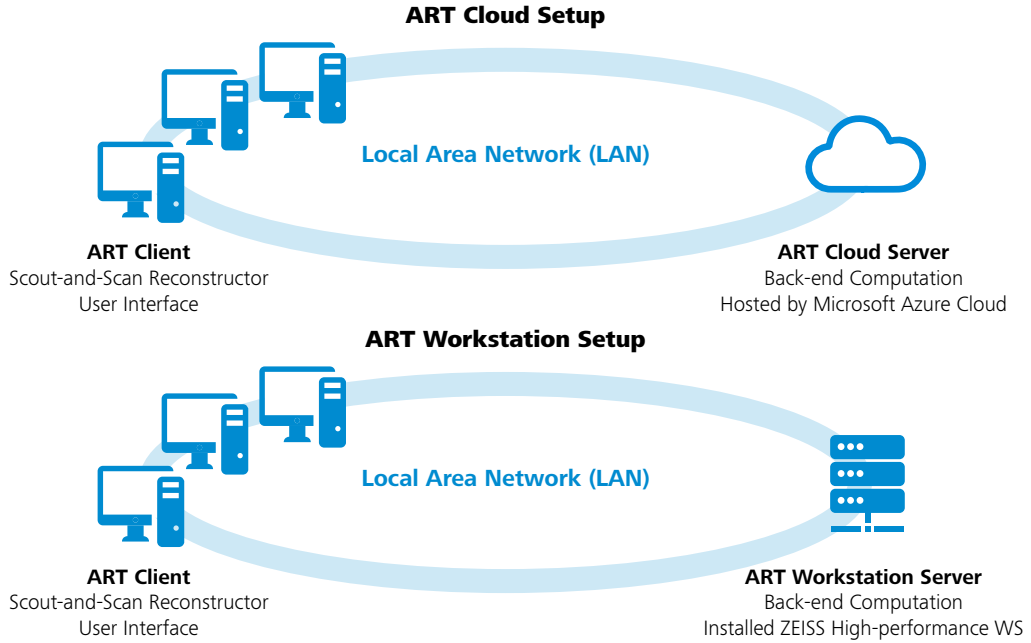
Access to ART: Meeting You Where You Are

Unique ART architecture provides you with options and flexibility that suit your working conditions.

Workstation: Access ART on a robust high-performance workstation, dedicated hardware with your choice of perpetual license and/or time-based licensing for all modules. This is your choice for the fastest processing of data for the full ART suite of capabilities.

Cloud: You can also access several ART modules via the cloud. Cloud access includes multi-seat setups with multiple access points without the need to make a capital investment. This provides access to the widest range of users with time-to-data based on your own IT infrastructure. The software you subscribe to is always up-to-date. And we ensure your data is secure.

Time-based Licensing: The ReconServer architecture supports time-based licensing for both Workstation- and Cloud-based access models. This is ideal when you have project-based work for which you may not need a perpetual license. You can easily upgrade your time-based license to a perpetual license if you determine this is the best structure for your requirements.



ZEISS ReconServer architecture provides up to three client seats per license in both Workstation- and Cloud-based setups. This enables access via the high-performance workstation (if applicable), other workstations (including on the instrument), or a laptop for remote working. Time-limited (1 year) licenses OR perpetual licenses are available on the workstation. Only time-limited (1 year) licenses are available on the cloud. Note: MARS & OptiRecon are NOT cloud compatible.

Work with your ZEISS representative to meet you where you are today and to determine the best solution, or combination of solutions, for your short and long-term needs.

Your Flexible Choice of Components

	DeepRecon Pro	DeepScout	PhaseEvolve	MARS	OpticRecon
System					
Versa	■	■	■	■	■
Context, Crystal CT	■	■	■	■	■
Ultra	■				
High-performance Workstation with perpetual licenses and/or time-based licenses	■	■	■	■	■
Cloud with time-based licenses only	■	■	■		
Packages					
AI Supercharger	■	■			
Artifact Reduction			■	■	
Recon Package	■				■
Premium ART	■	■	■	■	■

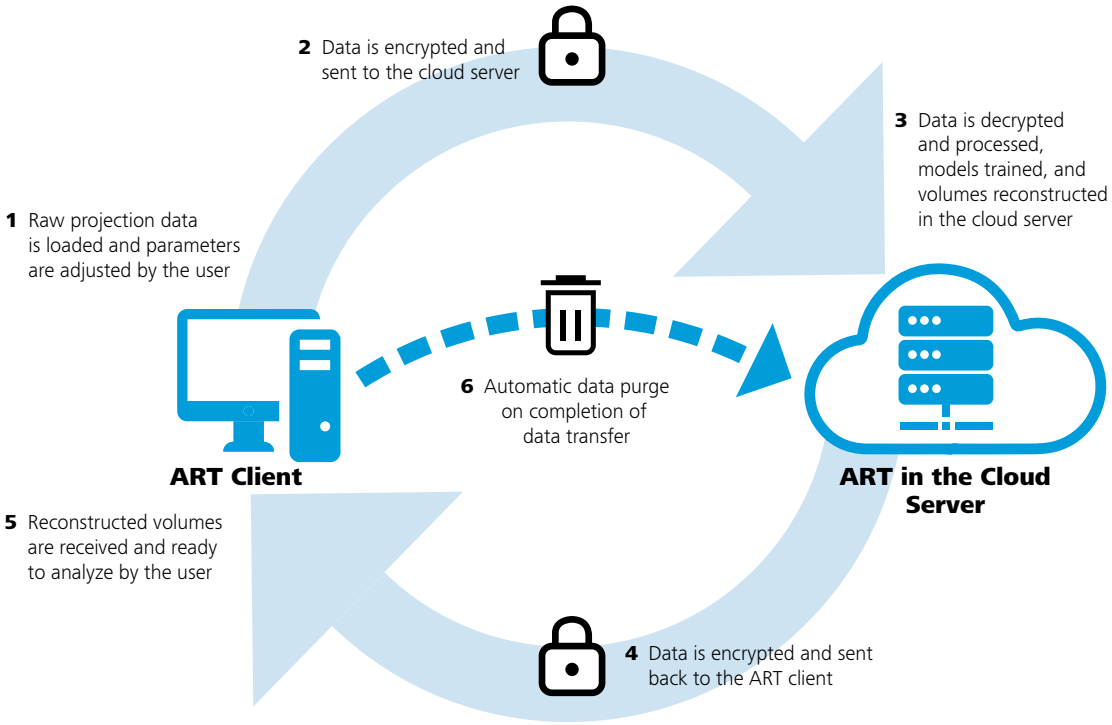
Stateless Processing for Maximum Security

Cloud Security

Your data, powering your experiences, is controlled by you. You have full control over sharing your data, results, and training models with your peers and collaborators. Your data is secured during processing and while in transit.

The core privacy principle from ZEISS is that you own your data. We fully respect your intellectual property rights, and the confidentiality of your data is our top priority. Therefore, access to cloud-based virtual machines is restricted to only select members of the ZEISS Research Microscopy Solutions Support and Operations team for support purposes only.

ZEISS uses Microsoft Azure for its cloud network. Each Azure geography contains one or more regions and meets specific data residency and compliance requirements, letting you keep your business-critical data and apps nearby on fault-tolerant, high-capacity networking infrastructure.



Stateless process for data security. Your data is secured during processing and while in transit. All data uploaded belongs to you and your organization only and you can feel confident about where your data is sent and how it is processed.

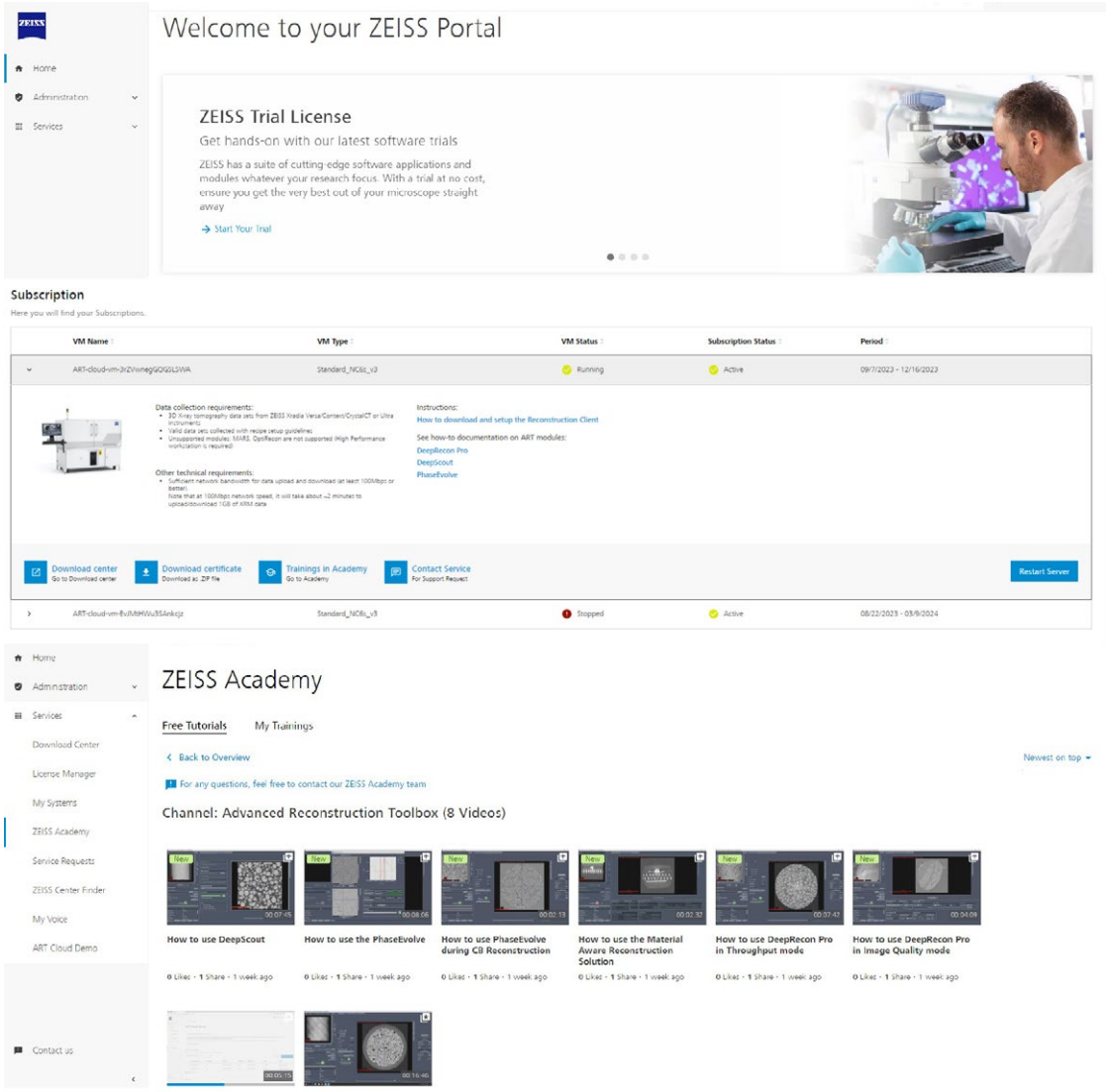
ZEISS Customer Portal: Your One-Stop Resource for ART in the Cloud

Getting Started is as Easy as 1-2-3
With your activation key, visit the ZEISS Portal to access your trial license.

The ART subscription window provides everything you need to rapidly engage in your trial, from registering your location to downloading the virtual machine.

ZEISS Academy provides demos and tutorials to help you make the most of your trial as quickly as possible.

To request a trial license, contact your ZEISS sales representative.



Technical Specifications

Protocols	HTTPS, secure WebSocket and encrypted data
Port	80
Certifications of Microsoft Azure	ISO 27001, HIPAA, FedRAMP, SOC1 and SOC2
Connection security	RSA 2048 and AES 256-bit encryption + TLS 1.3
Connection	RJ 45 connector for LAN (preferred) or Wi-Fi
Security patched and measured according to your local IT security standards	YES
Established and working outbound internet connection	YES *(recommended 100 Mbps minimum upload and download speed for optimal experience)*

ZEISS Service – Your Partner at All Times

Your microscope system from ZEISS is one of your most important tools. For over 175 years, the ZEISS brand and our experience have stood for reliable equipment with a long life in the field of microscopy. You can count on superior service and support - before and after installation. Our skilled ZEISS service team makes sure that your microscope is always ready for use.

Procurement

- Lab Planning & Construction Site Management
- Site Inspection & Environmental Analysis
- GMP-Qualification IQ/OQ
- Installation & Handover
- IT Integration Support
- Startup Training

Operation

- Predictive Service Remote Monitoring
- Inspection & Preventive Maintenance
- Software Maintenance Agreements
- Operation & Application Training
- Expert Phone & Remote Support
- Protect Service Agreements
- Metrological Calibration
- Instrument Relocation
- Consumables
- Repairs

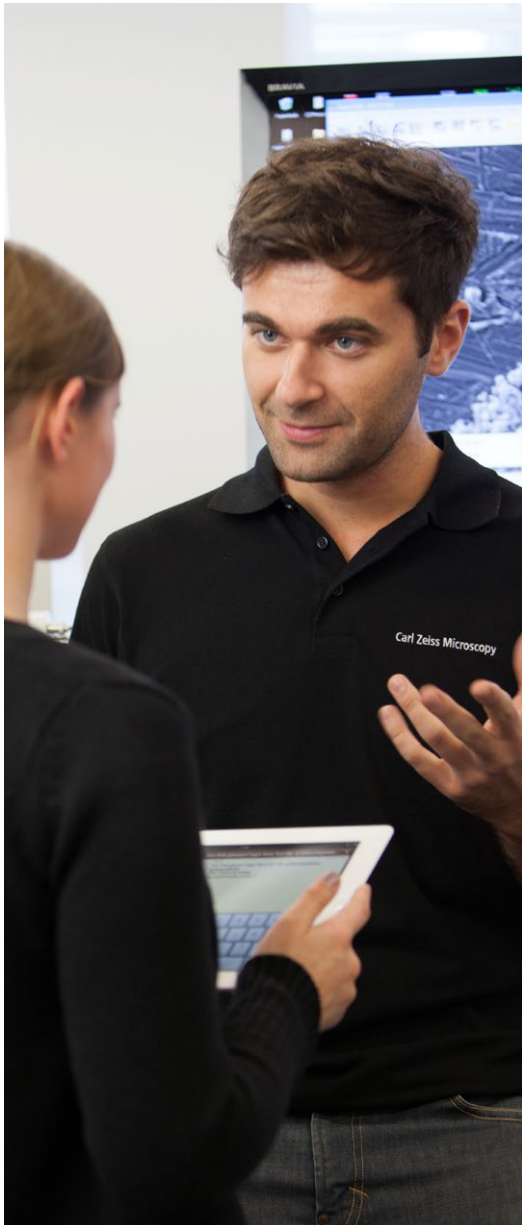
New Investment

- Decommissioning
- Trade In

Retrofit

- Customized Engineering
- Upgrades & Modernization
- Customized Workflows via ZEISS arivis Cloud

Please note: Availability of services depends on product line and location



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