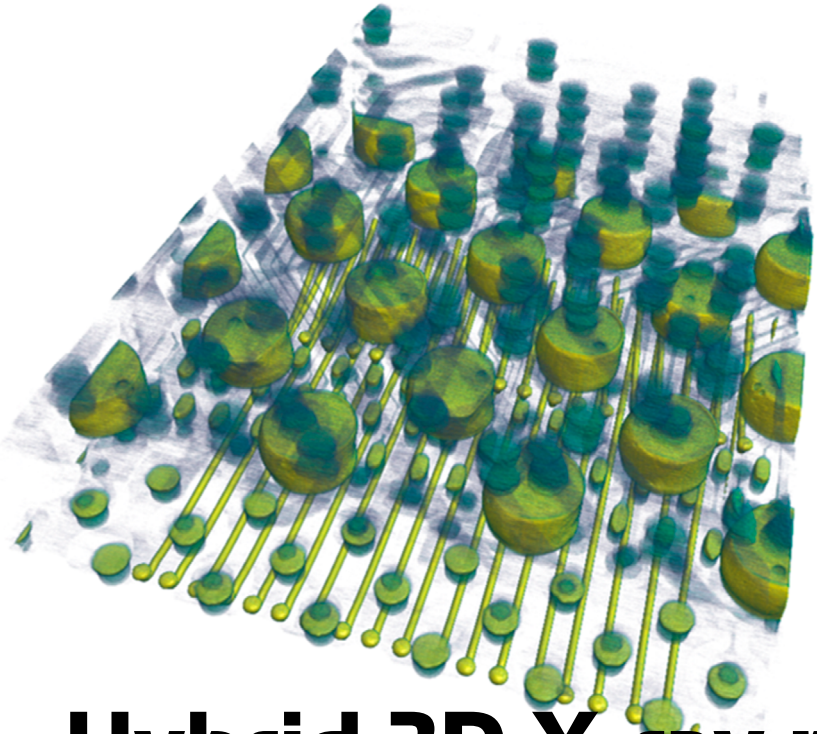
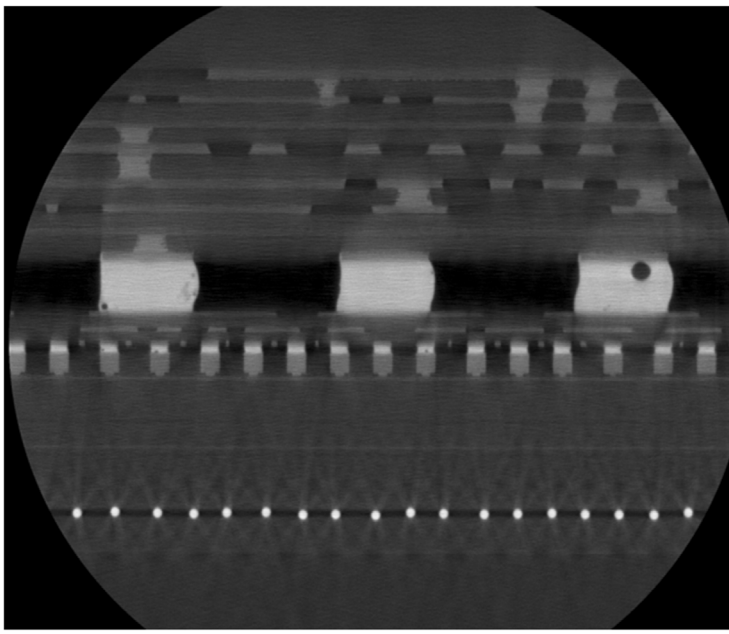
Technology note





Hybrid 3D X-ray microscopy: from fast sample overview to targeted high-resolution insight

Seeing **beyond**

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Date: **September 2026**

Overview

Modern research and scientific inquiry increasingly require non-destructive 3D imaging across multiple length scales to investigate internal structures while preserving sample integrity. A broad, full-sample view helps users understand geometry, locate internal features, and decide where deeper analysis should focus. Higher-resolution imaging then reveals the fine details that explain performance, failure, or structural variation.

Understanding where to look before investing time in high-resolution imaging is a critical step in many non-destructive 3D imaging workflows. Rapid overview scans provide the context needed to assess sample geometry, identify internal features, and prioritize regions of interest. Flat-panel-based microCT excels in this role by enabling fast imaging of larger sample volumes.

After identifying a target region, users often need higher-resolution data to understand the underlying structure in greater detail. X-ray microscopy (XRM) provides this capability, revealing features that are not visible in overview scans alone.

ZEISS VersaXRM 5 Insight™ brings these capabilities into one hybrid 3D X-ray microscope. It combines CT-style overview imaging, objective-based XRM, FAST mode acquisition, guided software workflows, and automated reconstruction tools so users can move from sample overview to targeted high-resolution insight in a single connected workflow.

Traditionally, these two imaging needs have been addressed using separate instruments, creating workflow inefficiencies associated with sample transfer, re-fixturing, additional setup, and the challenge of accurately relocating the same region of interest.

Why multi-scale imaging workflows matter

Many samples cannot be fully understood at one resolution. Batteries, electronics, additively manufactured alloys, biological specimens, and composite materials often contain large-scale structures that define context and small-scale features that explain behavior. Users often need to answer four fundamental questions during non-destructive 3D imaging:

- **Inquire:** What is inside the sample?
- **Explore:** How is the internal structure organized, and where are the features of interest?
- **Target:** Which region should be selected for higher-resolution imaging?
- **Discover:** What insights can be gained from detailed analysis of the selected region?

Figure 1 illustrates effective multi-scale imaging workflows that enable users to move seamlessly from Inquire and Explore activities at the whole-sample level to Target and Discover activities focused on regions of interest. XRM adds the ability to examine targeted internal regions at higher resolution while preserving the broader sample context.

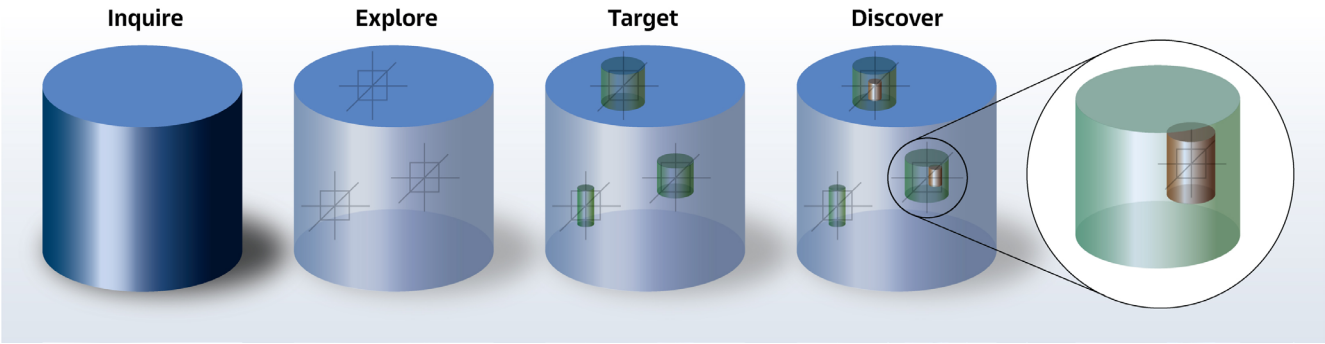


Figure 1: Transition from full-field-of-view imaging to high-resolution region-of-interest imaging within one instrument, one software environment, and one workflow.

CT and XRM: two complementary imaging approaches

MicroCT relies primarily on geometric magnification. To improve resolution, the sample or region of interest is positioned closer to the X-ray source and farther from the detector. This approach is effective for many overview and moderate-resolution scans, but it can be limited by sample size, sample shape, fixture geometry, or the need to maintain working distance.

X-ray microscopy extends beyond this constraint by using objective-based imaging. ZEISS Resolution at a Distance™ (RaaD™) technology enables high-resolution imaging of internal features while maintaining working distance between the sample and the source. This is particularly valuable for large, irregular, intact, mounted, or in situ samples where physical access to the region of interest is limited. As shown in Figure 2a, objective-based imaging complements traditional geometric magnification by enabling high-resolution imaging within larger or more complex samples while maintaining working distance. Figure 2b highlights the integrated hardware architecture that supports both overview and high-resolution imaging workflows.

The distinction is important: CT provides fast context; XRM provides targeted detail. VersaXRM 5 Insight is designed to make these capabilities work together rather than forcing users to choose between them.

Enabling hybrid CT – XRM imaging

VersaXRM 5 Insight supports hybrid imaging through an integrated detector and objective architecture. The flat panel detector enables efficient overview imaging with a large field of view and fast refresh times. It supports rapid initial scans, whole-sample inspection, and moderate zoom-in scans down to 1.5 µm spatial resolution.

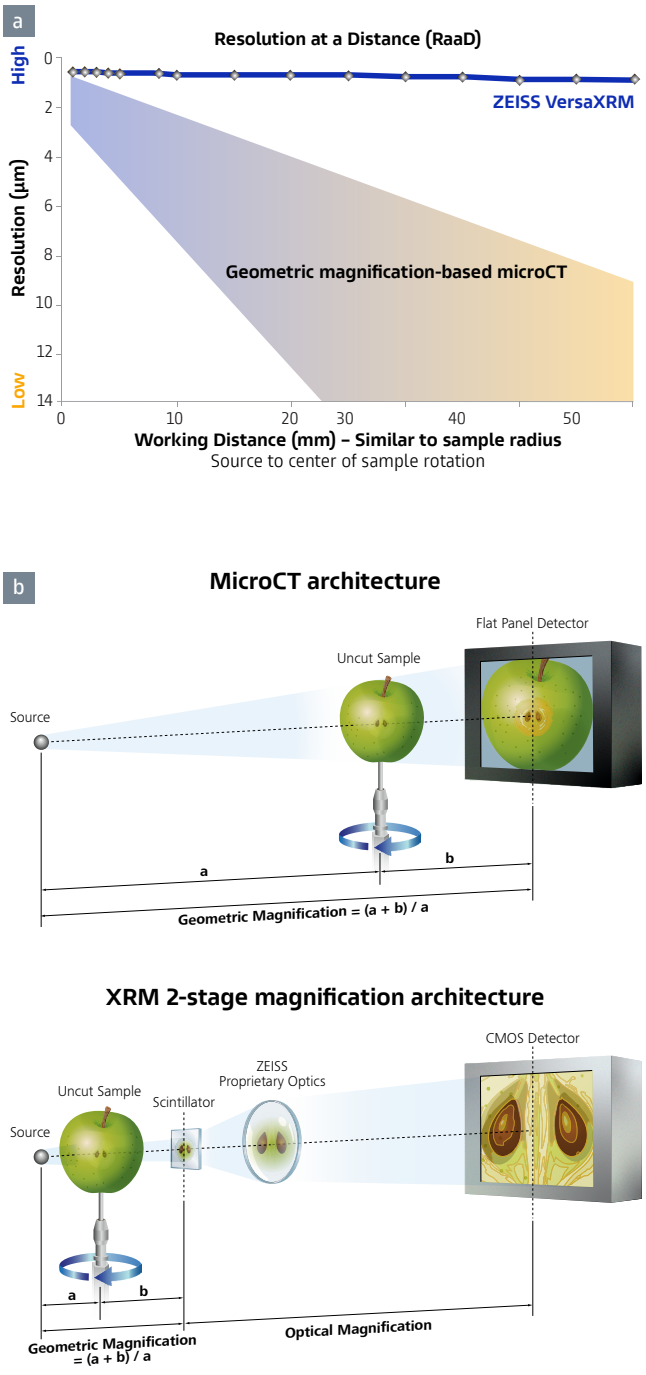


Figure 2 a) Illustration comparing conventional geometric magnification constraints to RaaD objective-based imaging for high-resolution analysis inside larger samples.
b) Overview of the hardware used for both traditional microCT-based and RaaD-based magnification.

For finer detail, the RaaD objective path provides high-resolution imaging capability down to 500 nm pixel resolution. The standard 4x objective and optional 20x objective allow users to target internal features after identifying them in the overview scan. A new camera box on the objective path also enables FAST mode for 4x RaaD imaging, further improving acquisition efficiency across the workflow.

As shown in Figure 3 the flat panel detector, RaaD objective path, updated camera architecture, and FAST mode capability create a practical hardware stack for multi-scale imaging: first locate the region of interest, then acquire higher-resolution data from the same sample setup.

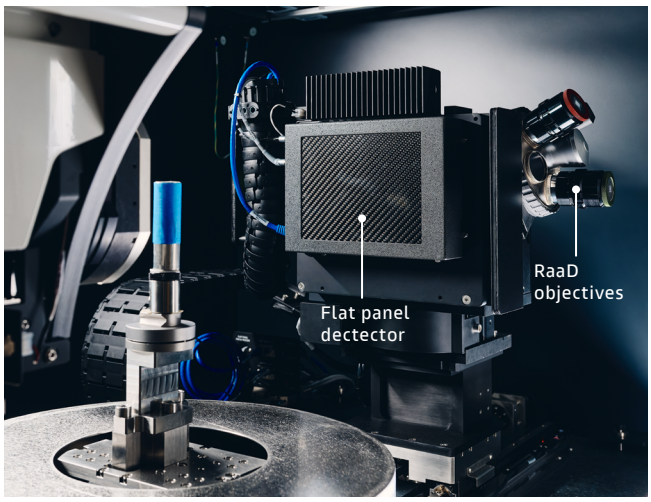
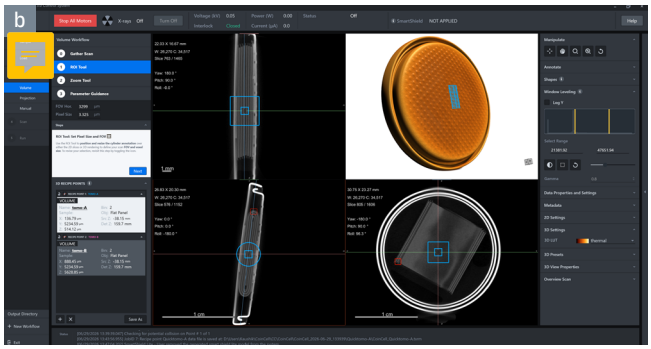


Figure 3: Instrument architecture schematic showing the integrated flat panel detector, objective-based XRM path, sample stage, and connected acquisition workflow.

Integrated Software for a Connected Workflow

ZEN navx® supports the full X-ray microscopy workflow, not only image acquisition. A typical workflow begins with a fast overview scan, continues with 3D navigation and region-of-interest selection, and then proceeds to targeted high-resolution imaging and reconstruction.



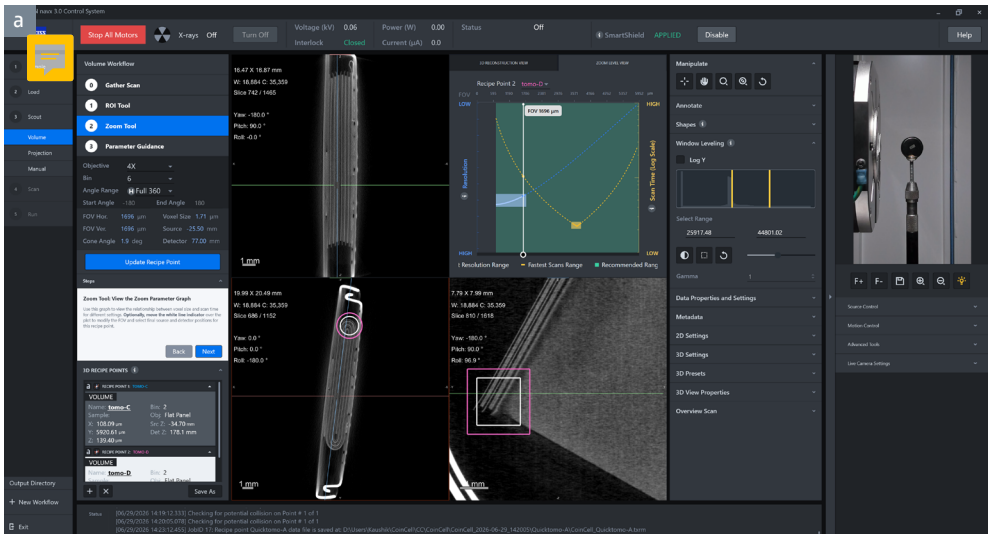


Figure 4: ZEN navx workflow illustrating (a) guided setup in the VolumeScout workflow, enabling selection of regions of interest using 3D spatial information, and (b) the Zoom tool, which assists in selecting the appropriate detector configuration and visualizing scan time versus resolution trade-offs to optimize acquisition settings.

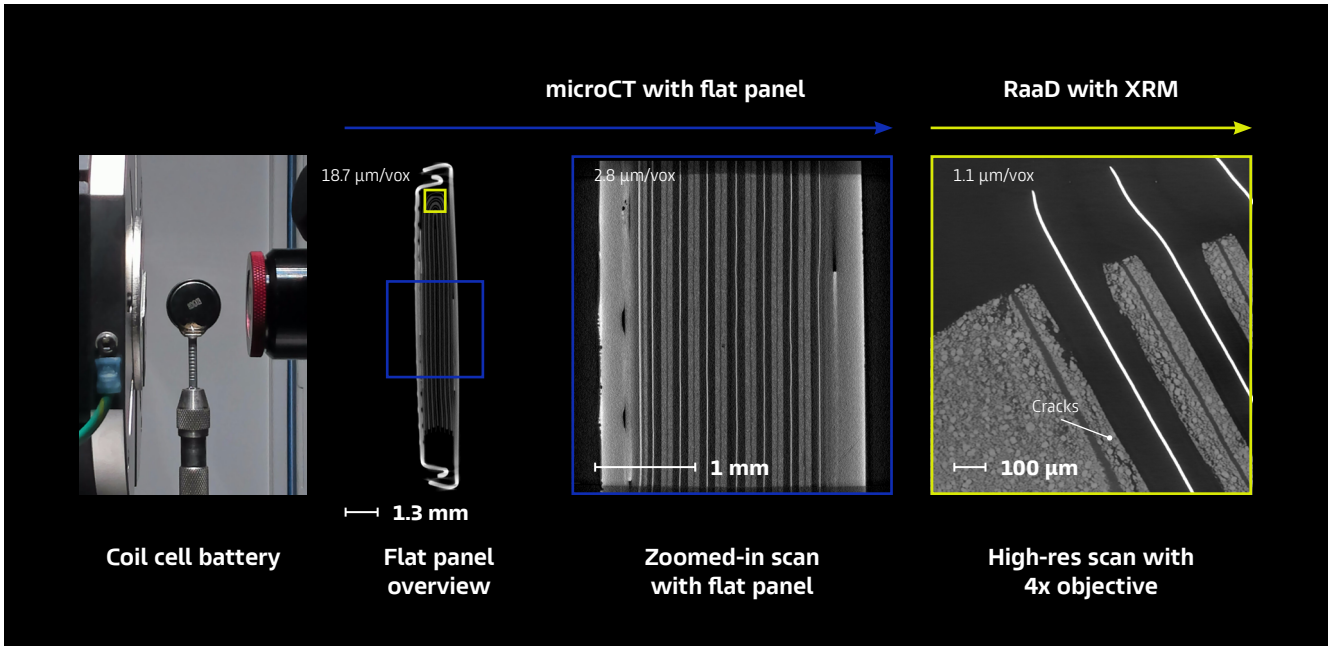


Figure 5: Four steps in a hybrid imaging workflow on coin cell battery: A fast overview scan provides full-sample context, followed by 3D region-of-interest selection, targeted high-resolution acquisition, and data interpretation. All imaging is performed on the intact sample within a single workflow without remounting or re-fixturing.

The overview dataset acts as a 3D map of the sample. Figure 4 shows a reconstructed 3D volume inside the VolumeScout workflow. The reconstruction shows the internal structure, orientation, and possible regions of interest. With the VolumeScout workflow, users can select one or more regions of interest directly within the 3D data. This reduces targeting uncertainty, especially for buried features that are difficult to locate from external appearance or 2D projections alone.

ZEN navx also supports scan setup through parameter guidance. Users can make informed choices about speed, resolution, field of view, and image quality based on the sample and imaging goal. Integrated reconstruction, including optional ZEISS DeepRecon Pro, helps move the workflow from acquisition to usable data with fewer manual steps and more consistent reconstruction quality.

Efficient imaging without sample preparation

One of the primary advantages of a hybrid CT-XRM workflow is the ability to seamlessly move from sample overview to targeted high-resolution imaging without changing instruments or disrupting the sample setup. As illustrated in Figure 5, users can first scout the complete sample, identify a region of interest within the intact sample, and then acquire higher-resolution data from the same sample setup without transferring or re-fixturing the sample. This reduces the number of manual interventions, physical transitions, and setup changes required throughout the imaging process. As a result, sample alignment is preserved, handling risks are reduced, and confidence that the same feature identified during overview imaging is the same feature being examined at higher resolution is increased.

FAST mode further improves workflow efficiency through continuous-motion scanning. Instead of repeatedly starting and stopping sample rotation, the sample rotates continuously while projection images are acquired. This reduces acquisition overhead and provides faster feedback for sample navigation, whole-part inspection, and region-of-interest targeting.

These workflows are accessible across experience levels. Guided workflows help new users generate reliable results more efficiently while learning key concepts in X-ray CT and microscopy. Expert users retain manual control when they need to define acquisition regions, adjust parameters, or create specialized recipes.

The result is a workflow that preserves both sample integrity and spatial context while reducing time between overview imaging, region-of-interest selection, and detailed characterization.

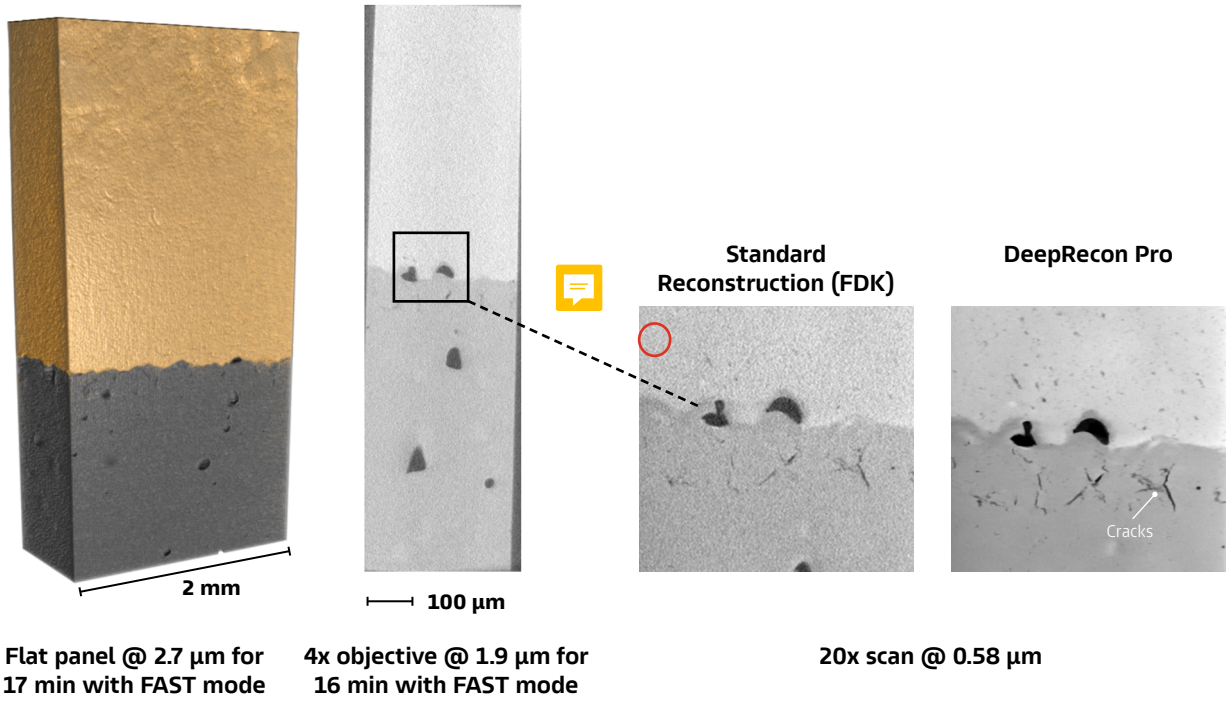


Figure 6. An additively manufactured Cu-steel functionally graded material. With FAST mode for both the flat panel and 4x objectives, researchers can obtain high-resolution images in a fraction of the time compared to traditional imaging. The 20x objective enables detailed characterization of regions of interest at submicron resolution. Applying DeepRecon Pro further enhances the image quality, revealing key features such as internal defects and cracks.

Practical application workflows

The benefits of hybrid CT-XRM imaging extend across a wide range of applications. The following examples demonstrate how users can combine full-sample overview imaging with targeted high-resolution characterization while maintaining sample context and avoiding unnecessary sample preparation.

Materials science and additive manufacturing. Users can scan a full sample to locate cracks, pores, inclusions, interfaces, or process-related defects, then target selected regions for higher-resolution analysis. For example, the Cu-steel interface in Figure 6 can be scouted with the flat panel detector in FAST mode and then examined with a 20x objective to reveal submicron interfacial features.

Energy storage and batteries. Users can visualize full-cell geometry, then target electrode layers, pores, particles, cracks, or local defects for higher-resolution imaging while maintaining full-cell context. Figure 7 shows a cylindrical 21700 battery imaged using the flat panel detector to capture the complete cell geometry. A targeted high-resolution scan of the highlighted region reveals the internal layered electrode structure in greater detail. This example demonstrates how users can move from full-cell inspection to localized characterization without sectioning or disassembling the battery.

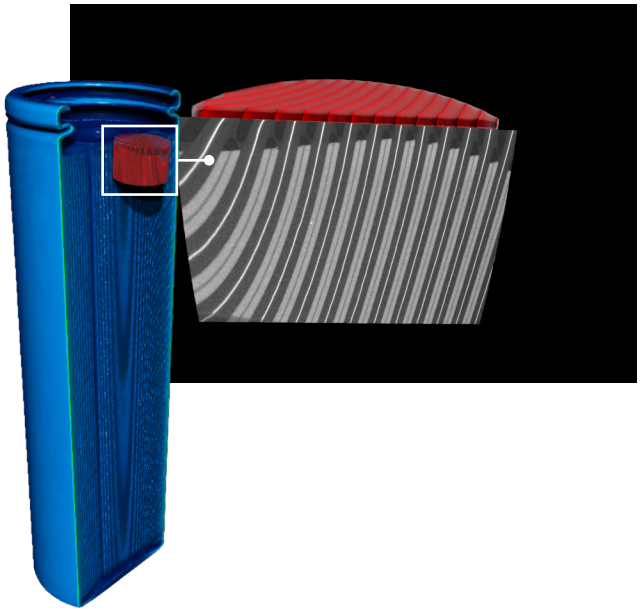


Figure 7. Flat panel imaging of a cylindrical 21700 battery (70 mm × 21 mm) showing full cell on left using flat panel at 70 µm (60 mins), and a magnified view of red inset region on the right acquired at high resolution (3.5 µm) highlighting the internal layered structure for detailed, non-destructive characterization.

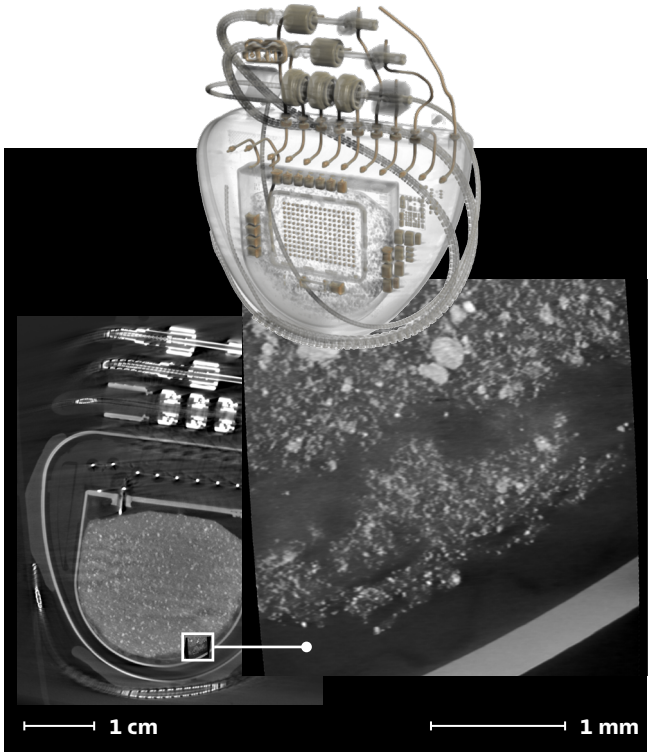


Figure 8. 3D visualization of a pacemaker illustrating the seamless multi-scale zooming capabilities, from rapid overview with flat panel with FAST mode in 10 min to targeted high-resolution analysis of internal features at 3.5 µm with 4x objective.

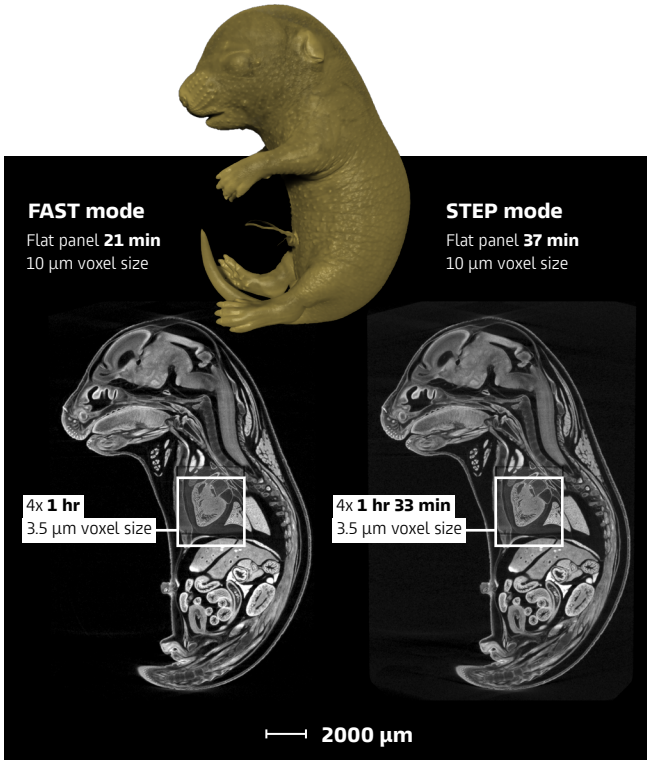


Figure 9. The mouse fetus was imaged using the flat panel at 10 µm overview resolution, followed by a zoom scan using the 4x objective with 3.5 µm voxel size (inset). In continuous rotation FAST mode, the flat panel scan was completed in 21 minutes, compared with 37 minutes in STEP mode. Similar throughput gains were observed for the 4x objective, where the 4x FAST mode scan was 33 minutes faster while maintaining image quality. Sample courtesy of Dr. Chih-Wei Logan Hsu, Baylor College of Medicine, TX, USA.

Industrial research and failure analysis. Hybrid CT-XRM workflows allow users to rapidly inspect a complete component, identify suspicious regions, and acquire higher-resolution data from areas of interest without losing spatial context. The pacemaker example in Figure 8 illustrates this workflow by combining rapid overview imaging in 10 minutes with targeted high-resolution analysis of internal features. This demonstrates how users can navigate from a complete assembly to specific structures of interest while maintaining a clear understanding of how those features relate to the overall device architecture.

Life sciences Biological specimens frequently require preservation of whole-organism context while enabling detailed investigation of specific anatomical structures. Hybrid CT-XRM workflows support this need by combining non-destructive overview imaging with targeted high-resolution visualization of selected regions. The mouse fetus example in Figure 9 demonstrates how an overview scan captures the complete specimen while a subsequent zoom scan reveals finer anatomical detail within a selected region. The example also highlights the benefits of FAST mode acquisition, which reduces scan times by 33% while maintaining image quality and enabling more efficient imaging workflows for biological samples.

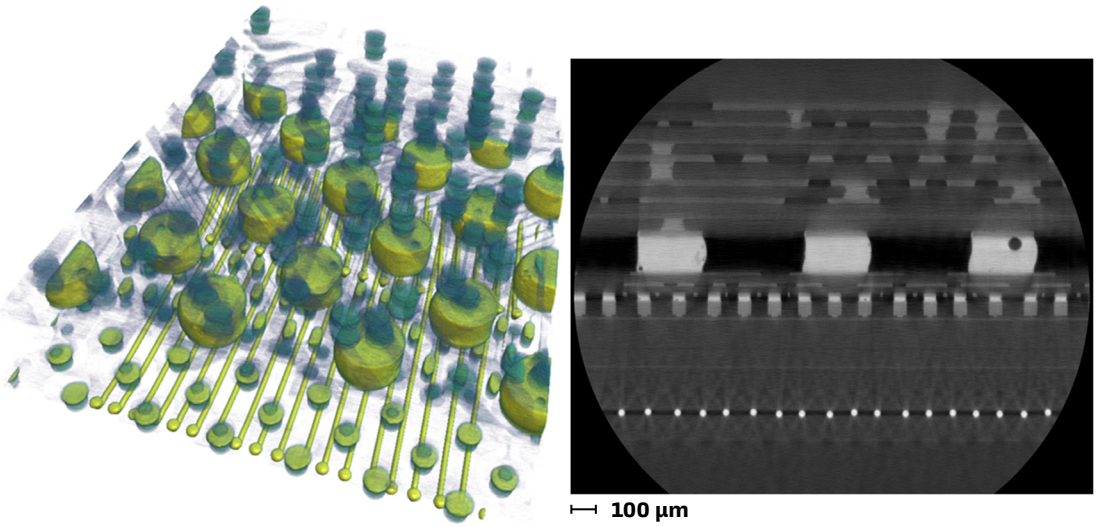


Figure 10. 3D reconstruction of a 5G modem package on a smartphone board. The left image shows the C4 bump and microbump architecture, and the right image displays a reconstructed slice of the corresponding internal interconnect structure acquired at 0.8 µm / voxel using a 4x objective.

Electronics and semiconductor packages. Users can capture full-package context, then target solder joints, interconnects, vias, delamination, voiding, or other buried features. Pictured in Figure 10, the 5G modem example shows a complete package reconstruction alongside a high-resolution view of the internal interconnect architecture. The overview image provides device context, while the higher-resolution dataset reveals structural details that are critical for package development, quality assessment, and failure analysis.

Conclusion

Hybrid 3D X-ray microscopy is a non-destructive technique connecting fast sample overview with targeted high-resolution detail. VersaXRM 5 Insight combines CT-style flat panel imaging, RaaD objective-based XRM, FAST mode acquisition, guided software workflows, and automated reconstruction to support efficient multiscale 3D imaging.

The key benefit is workflow continuity. Users can locate features, define regions of interest, acquire higher-resolution data, preserve sample context, avoid unnecessary re-fixturing, and move from acquisition to interpretation within a unified environment. This helps laboratories generate reliable 3D insight more efficiently while protecting valuable samples and reducing user effort.

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