SkyScan 1276

- High Resolution *In-Vivo*
  X-Ray Microtomograph

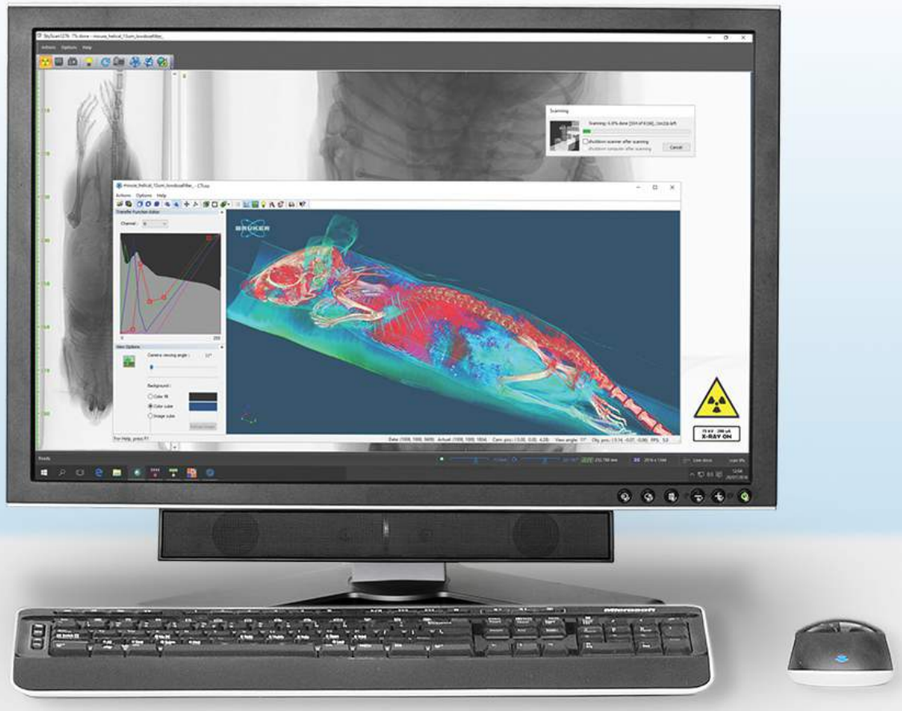
MICROTOMOGRAPHY

Innovation with Integrity

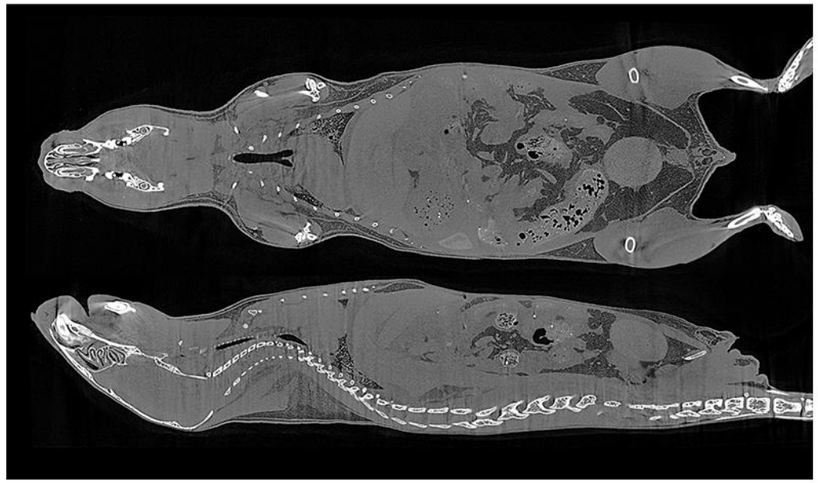
SkyScan1276:
High-Resolution, Fast, *In-Vivo* Desk-Top X-Ray Microtomograph

Best Specs for Animal and Sample Scans

- Continuously variable magnification with 2.8 µm highest nominal spatial resolution
- Step-and-shoot and continuous gantry rotation with 3.9 seconds shortest scanning cycle
- Up to 8000x8000 pixels in every reconstructed slice with more than 1600 slices in a single scan
- Circular and spiral (helical) scanning, unlimited gantry rotation due to slip ring connection
- Standard, GPU-accelerated and world's fastest InstaRecon® hierarchical reconstruction with speed-up more than 10 times compared to conventional reconstruction algorithms
- Peak X-ray energy adjustable to any value from 20 to 100kV; 6-position automatic filter changer
- Spatial beam shaper invented by **Bruker microCT** reduces dose 2-3 times with minimal impact to the image quality
- Integrated physiological monitoring with breathing sensor, ECG, temperature stabilization and body movement detection, 4D (time-resolved) cardiac and respiratory microtomography
- Easily replaceable mouse and rat cassettes with anaesthetic gas mask and electrical connections to all physiological sensors can be inserted and removed by a single click
- On-screen dose meter indicates applied dose to the animal based on information from analysis of X-ray projection images
- Integrated touchscreen allows control of main system functions by gloved hands
- Results of reconstruction can be directly sent to mobile devices, such as iPad, iPhone or Android phones and tablets, for volume rendered 3D viewing using supplied software
- The system is supplied with a GLP (Good Laboratory Practice) software package



Best Results in Any Application

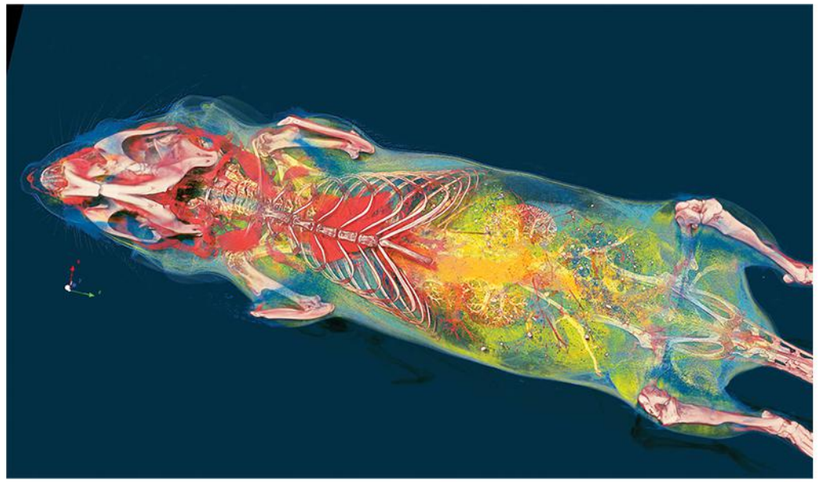


FULL BODY SCAN

Coronal and sagittal reconstructed slices from a full body scan of a mouse.
No contrast agents.

17 µm voxel size,
75 kV, Al 1mm filter

2016x2016x6223 pixels reconstructed volume

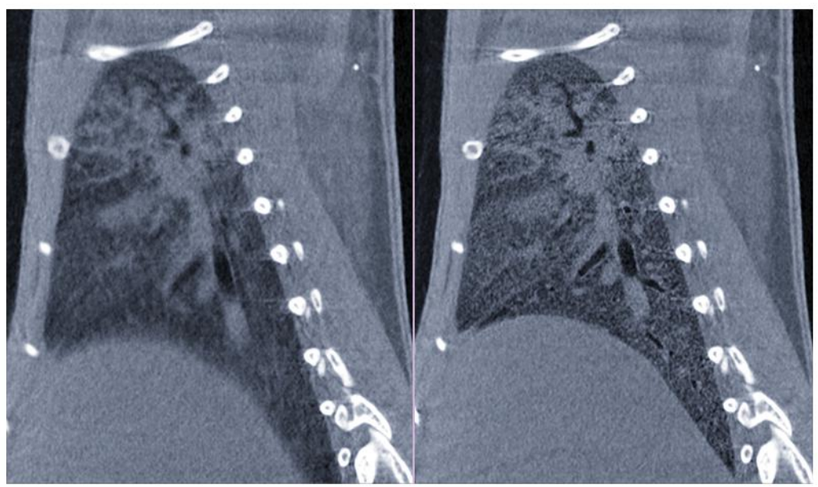


CONTRAST AGENT

3D volume rendering of full body scan of a mouse with contrast agent injected.
Spiral (helical) scan.

17 µm voxel size,
75 kV, Al 1 mm filter

2016x2016x6554 pixels reconstructed volume



RESPIRATORY GATING

Sagittal reconstructed slice through a mouse lung obtained without (left) and with (right) synchronization with respiration.

26 µm voxel size,
60 kV, Al 0.5 mm filter

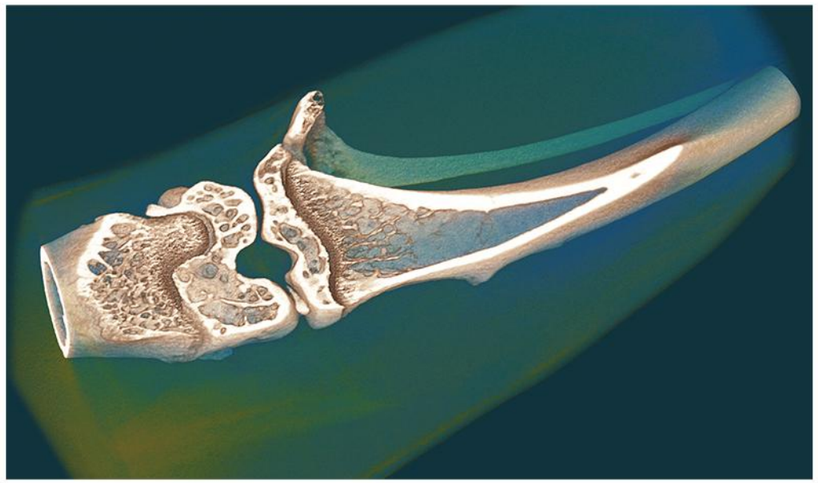
1008x1008x598 pixels reconstructed volume

KNEE

In-vivo scan of a mouse knee

6.5 µm voxel size,
60 kV, Al 0.5 mm filter

2000x2000x1965 pixels reconstructed volume

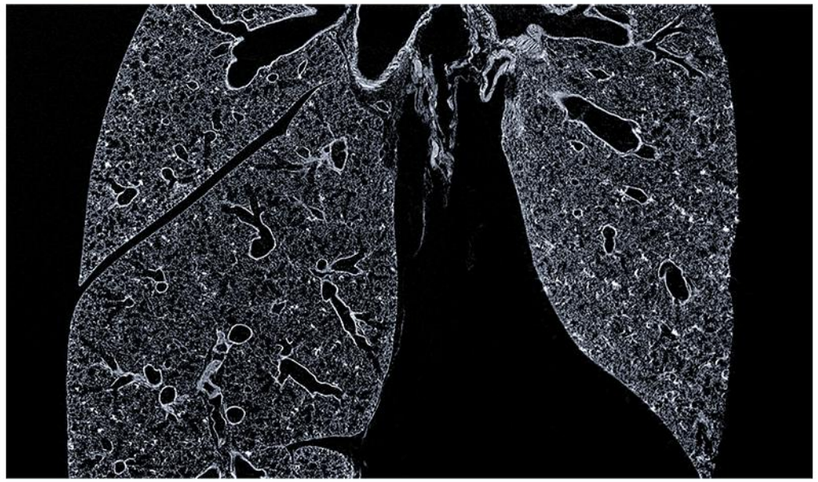


LUNGS

Reconstructed slice through the lungs of a mouse

3.08 µm voxel size,
50 kV, Al 0.5 mm filter

3798x2232 pixels slice from 4032x4032x2232 reconstructed volume

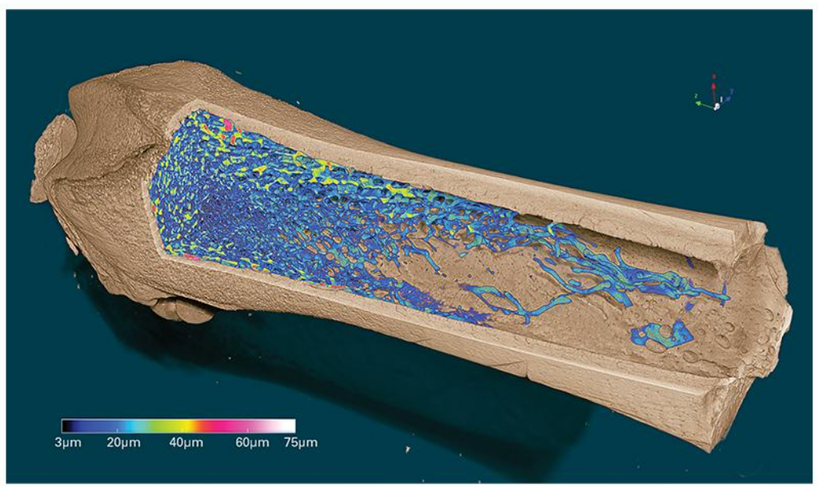


BONE

3D volume rendering of a rat bone with color coded local trabecular thickness

2.8 µm voxel size,
80 kV, Al 1 mm filter

4032x4032x7693 pixels reconstructed volume



Easy Control, Enjoyable Experience

The user interface of the SkyScan 1276 is easy and intuitive. All functions can be selected by standard Windows-type menu in the top of the program window.

A toolbar provides access to frequently used functions. Simply click the toolbar buttons from left to right to start the X-ray source, get real-time X-ray images to adjust magnification and scanning location, check a single image using the acquisition protocol, inspect the object by visual camera, start scanning and reconstruction, etc. The toolbar buttons can be customized by the user.

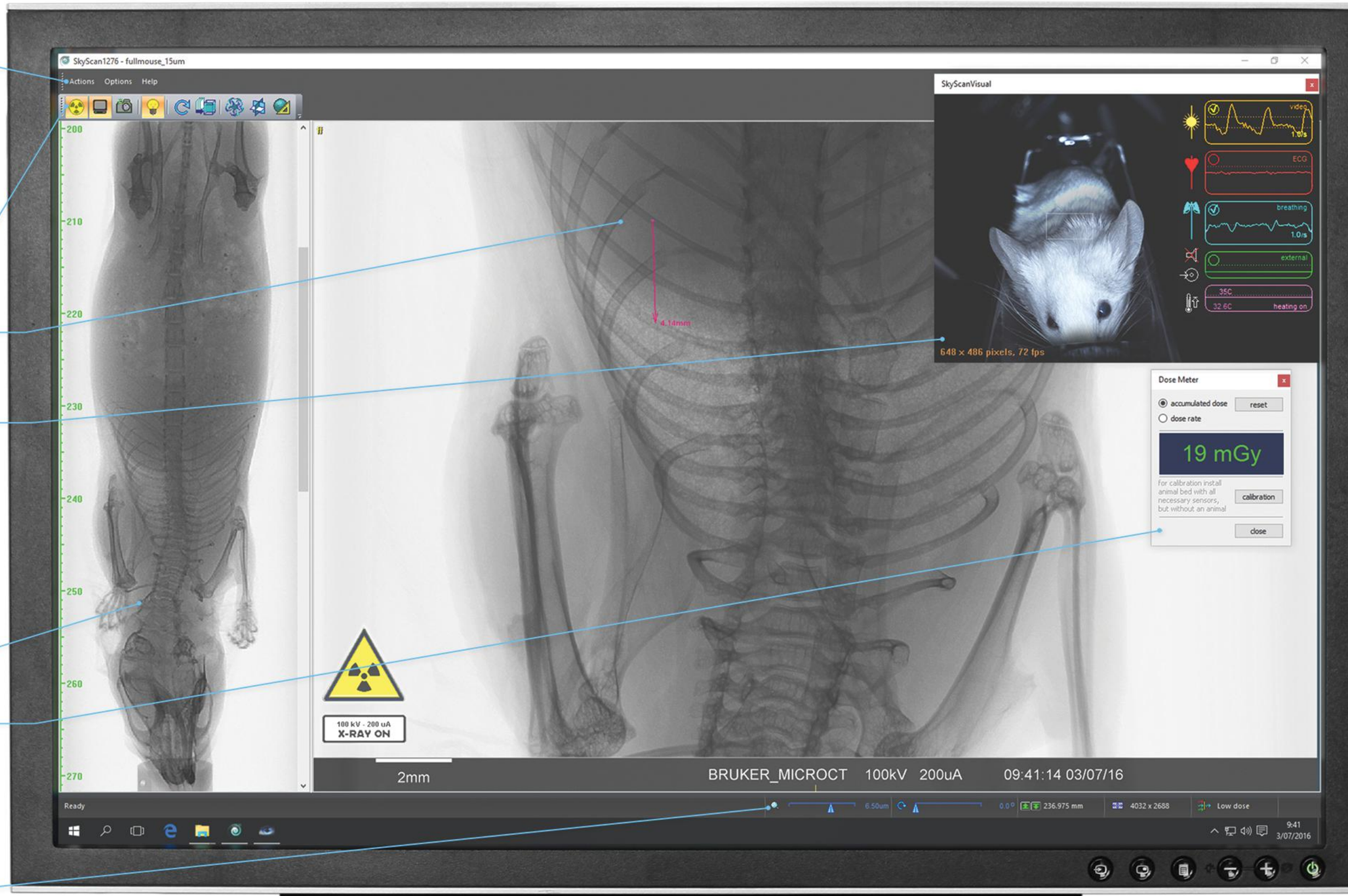
Filling the center of the window is the current image from the X-ray camera. One can measure dimensions of the features by dragging the mouse cursor over the image or drag-and-drop to move the animal bed to a new location.

A 5Mp color visual camera allows you to view the animal and perform body movement detection in real time. The breathing and ECG signals are also displayed as real-time profiles on-screen.

The scout view shows the image of the animal over a scannable range of more than 300mm. The operator can select a scan between any two longitudinal positions. If the selected length cannot fit in a single camera field of view, the scan will still comprise a continuous single volume either from a number of overlapped sub-scans with automatic connection, or using a spiral (helical) trajectory. The scout view also allows selection of multiple scans of different length, which can be executed in batch mode with individual scanning protocols.

An on-screen dose meter indicates accumulated dose or current dose rate, based on X-ray absorption calculated from projection images of the animal body.

The status bar at the bottom of the program window contains the sliders for direct magnification and angular position control, buttons for moving the animal bed, selection of image formats and selection of energy filters.
The software can assist by automatic selection of the optimal energy filter and voltage in the X-ray source according to absorption in the scanning area.



Animal Handling

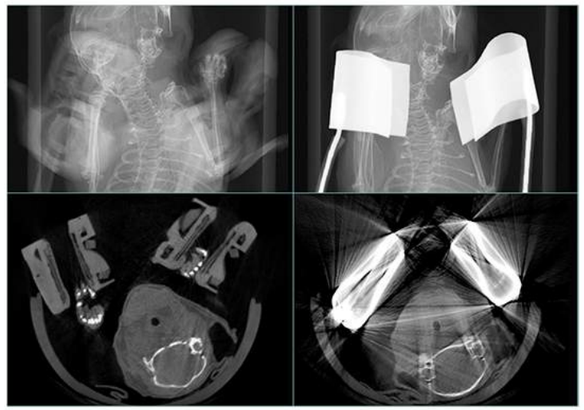
MOUSE AND RAT CASSETTES

The SkyScan 1276 system is supplied with exchangeable animal cassettes that can be used in all Bruker *in-vivo* imaging instruments such as MRI, micro-PET, micro-SPECT, bio-luminescence, bio-fluorescence, etc. to collect multimodal information. It allows co-registration of functional and morphological information from the same animal.

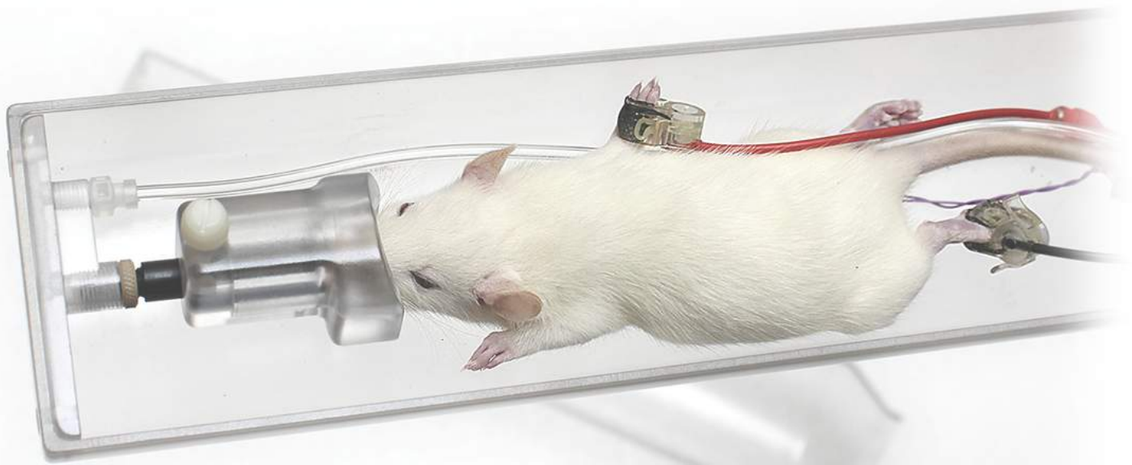
The cassettes are equipped with face masks and tubes for anaesthetic gas as well as with connectors for ECG electrodes and a temperature sensor. All tubes and contacts are combined in a single connector, which can be attached to or detached from the animal transport system by simple turn of a small slider. To prevent leakage of anaesthetic gas, corresponding connections have valves which close when the animal cassette is disconnected from the animal transport system.

ALL-CARBON ECG ELECTRODES

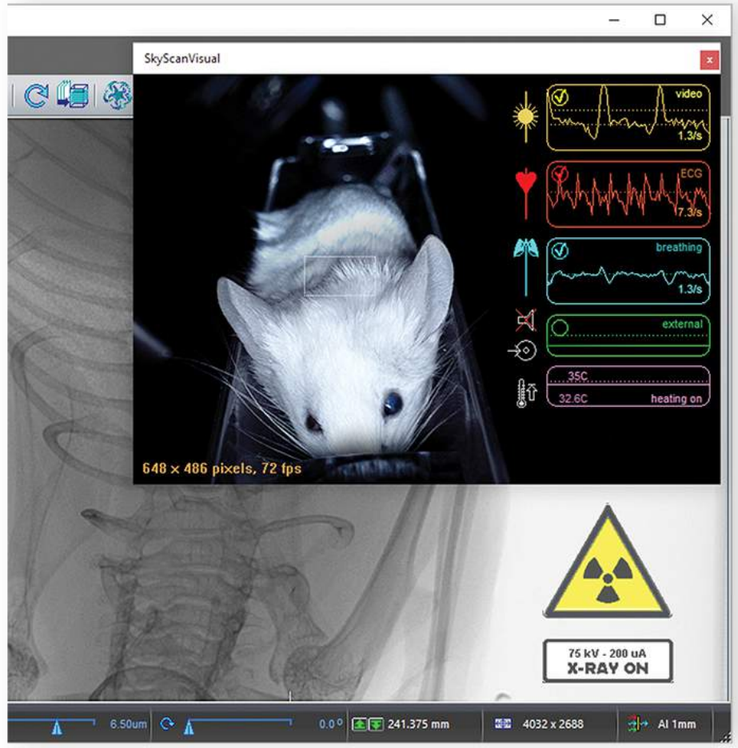
The animal cassettes include special connectors for clip electrodes to detect ECG signals by a sensitive amplifier integrated in the physiological monitoring sub-system. The ECG connections use wiring and electrodes, specially developed by **Bruker microCT**, which contain no metal parts. The wires and electrodes employ advanced carbon-fiber conductive parts with X-ray absorption similar to that of animal tissues for uncompromised image quality.



Shadow projections (top) and reconstructed slices through a mouse body (bottom) with attached carbon electrodes developed by **Bruker microCT** (left) and with conventional metal electrodes (right) >



Physiological Monitoring, Time-Resolved Scanning



PHYSIOLOGICAL MONITORING

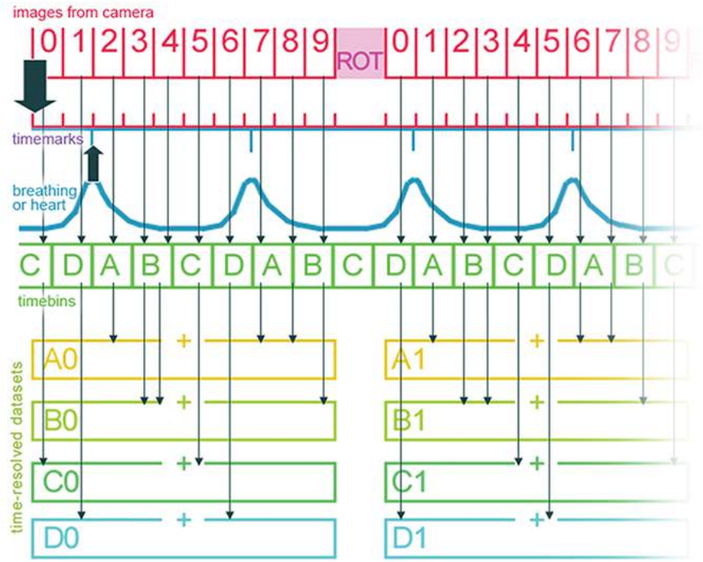
The physiological monitoring sub-system includes video monitoring of an animal with real-time movement detection, ECG and breathing detection, and temperature stabilization. A 5 megapixel color TV-camera is mounted above the animal bed along with white LED illumination to produce a real-time image of the animal during the scan. The software analyses the video stream from a user-selected area of the image, which the operator can position on a part of the animal body (or a marker object) where breathing movement is visible. These movements are converted into a movement waveform to provide breathing time marks for time-resolved micro-CT reconstruction.

The face mask on the animal bed is connected to an air/gas flow sensor for direct breathing detection. The ECG electrodes in the animal cassette are connected to a sensitive ECG amplifier. Both breathing and ECG signals are digitized, sent to the computer and displayed as real-time profiles on-screen. An operator can select individual gain and threshold for each signal to optimize generation of time marks. The monitoring also includes temperature stabilization by heated airflow, which maintains the scanned animal at a selected temperature, to prevent cooling of the animal under anaesthesia.

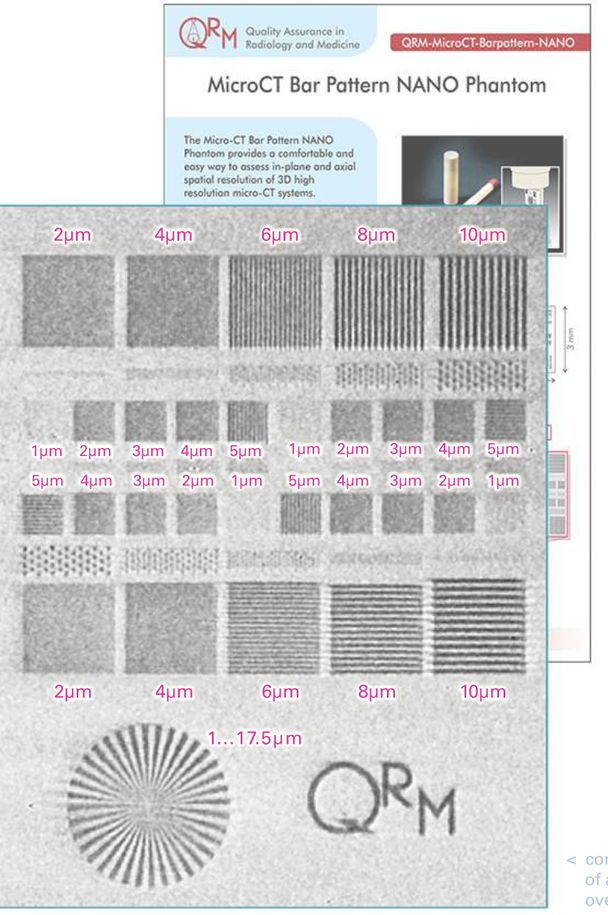
4D TIME-RESOLVED MICROTOMOGRAPHY

Physiological monitoring creates reference time-marks for time-resolved reconstruction of heart and lung dynamics. In this scanning mode, multiple projection images taken at each gantry angular position are sorted post-scan into breathing or heart time bins using recorded physiological monitoring time marks. Such sorting creates pseudo-static sets of projections, which are reconstructed as separate datasets and produce 4D set of results corresponding to the different phases of the cardiac or respiratory cycle.

Our visualization program loads all reconstructed datasets and allows scrolling in XYZ dimensions across the reconstructed volume as well as in the time-dimension to demonstrate the dynamics of heart or lung movements in sharp reconstructed images minimally affected by movement artifacts. Because all acquired data are sorted after the acquisition process, both respiratory and cardiac cycles can be visualized from the same scan by sorting according to time marks from the corresponding physiological monitoring channel.



Highest Spatial Resolution, Strict Dose Monitoring



PROOF OF TRUE SPATIAL RESOLUTION

The spatial resolution which can be achieved by micro-CT instrument often quoted as the smallest pixel size (also named as the "nominal resolution"). The true spatial resolution however depends not only on the pixel size in the image. It is also limited by the spot size in the X-ray source, by drift of the emission point position, by mechanical accuracy of the system, by processing and reconstruction algorithms and by many other factors. In *in-vivo* micro-CT systems with the X-ray source and camera mounted on a gantry, the mechanical accuracy and stability of gantry rotation play a crucial role in reaching the micron level of spatial resolution. Providing the possibility to change image magnification by moving the X-ray source and camera on the gantry adds extra complexity to the reaching high magnification and resolution.

The SkyScan1276 possesses number of unique design solutions to ensure the possibility of reaching true spatial resolution in the micron range. The combination of a smallest pixel size of 2.8 µm, a spot size in X-ray source under 5 µm, gantry mechanics with micron level of accuracy and stability and a highly accurate 3D reconstruction procedure allows the attainment of overall true system resolution in reconstructed slices at the level of 5 µm.

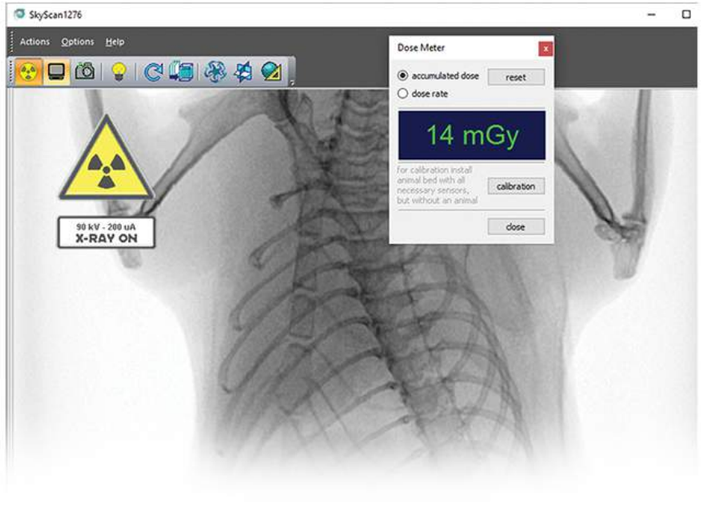
To prove true spatial resolution, specially designed image phantoms can be used as objects for scanning and reconstruction. One such phantom specially designed to assess spatial resolution in micro-CT systems is produced by the company QRM in Germany (www.qrm.de). It contains two identical silicon chips in orthogonal orientations, each having a number of linear and star patterns with calibrated line thicknesses in the range from 10 µm down to 1µm. Scanning and reconstruction of such a phantom proves a usable 3D spatial resolution in the SkyScan1276 at the level of 5 - 6 µm with more than 10% contrast from such small details.

< coronal slice obtained by the SkyScan1276 in scanning and reconstruction of a QRM bar pattern phantom at 2.8 µm pixel size demonstrates 5 µm overall 3D system resolution in any spatial direction.

ON-SCREEN REAL-TIME DOSE METER

The SkyScan1276 control software includes a real-time on-screen dose meter. It indicates an estimation of the dose absorbed by the animal body during scanning. The measurement is based on the absorption calculated from X-ray projection images of the animal cross-calibrated with electronic dosimeter measurements.

The dose meter shows accumulated dose or dose rate. It is calibrated for X-ray absorption in the standard mouse and rat cassettes. In this way it measures the X-ray dose absorbed in animal body itself during scanning. The dose absorbed by the animal during a scan is documented in the scan log-file together with all scan and reconstruction settings.



Touchscreen Control, Circular and Spiral Scanning

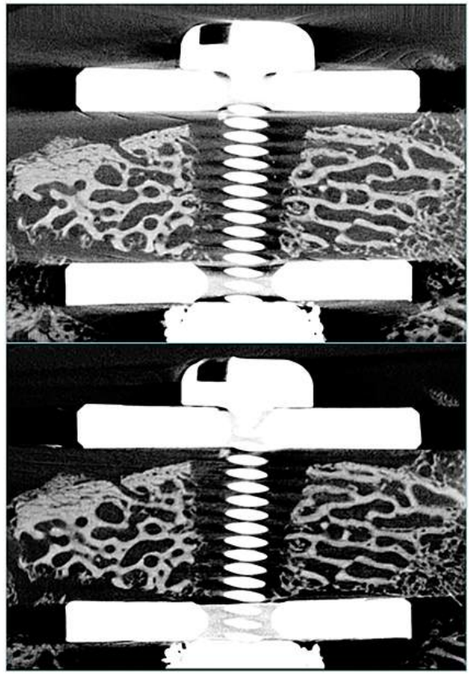
INTEGRATED TOUCHSCREEN

The user interface of the SkyScan1276 system is simple and intuitive. The instrument can be controlled from the computer screen and also from the embedded force-sensitive touchscreen, which can be operated by gloved hands. The touchscreen allows selection of scanning protocol, adjusting the animal bed position and control of imaging and scanning. Where multiple scans are started from the touchscreen, the software will automatically save acquired data to separate subfolders with incrementally assigned folder names and dataset file prefixes.

Full flexibility of scanner functionality is achieved by a straightforward standard Microsoft Windows user interface on the control workstation. It allows flexible adjustment of X-ray source and detector settings as well as control of all scanning parameters. A set of all instrument settings can be saved as a user configuration, allowing reload of settings by one click for future scans.

VARIABLE X-RAY ENERGY, FILTERS AND BEAM SHAPER FOR LOW-DOSE SCANNING

The SkyScan1276 uses an X-ray source with adjustable power and applied voltage in the range of 20-100kV. In combination with a motorized six-position filter changer it provides optimal scanning protocols for *in-vivo* studies taking into account size of animals and dose requirements. One of the positions in the filter changer is occupied by a so-called "low-dose" filter, which is a unique X-ray beam shaper patented by **Bruker microCT.** It creates variable filtering conditions across the scanning area and reduces dose to the animal 2-3 times without compromising image quality of the reconstructed results.



CIRCULAR AND SPIRAL SCANNING

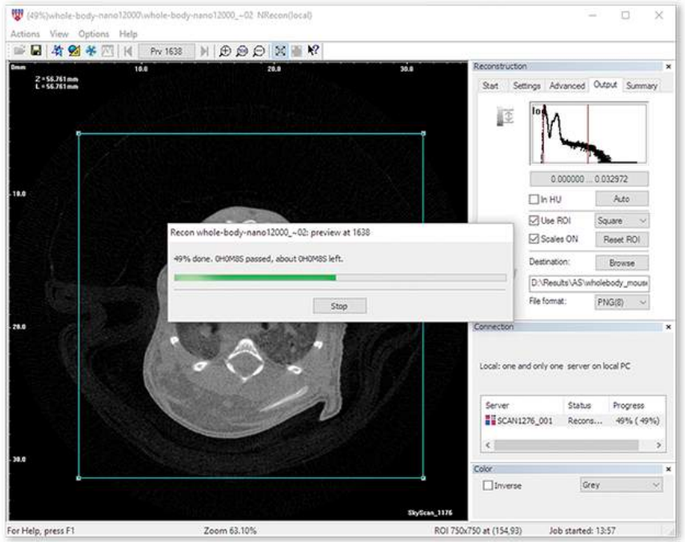
The SkyScan1276 can perform scanning using circular trajectory when the gantry rotates during scanning to obtain different angular views and by spiral (helical) trajectory when the animal is moving through the scanning area simultaneously with gantry rotation. The supplied reconstruction program supports both scanning approaches and performs highly accurate 3D reconstruction from spiral (helical) scans. Using spiral trajectory eliminates ring artifacts and blurring artifacts at surfaces perpendicular to the gantry axis at high cone angles and allows coverage long samples or animals by a continuous scan.

The SkyScan1276 can also perform conventional scanning and reconstruction using circular trajectory to produce high-quality results with shorter scanning time compared to spiral (helical) scanning. To cover a long scanning area, the SkyScan1276 makes multiple scans with round trajectories and automatically merges them during reconstruction into a single continuous set of results. The reconstruction program supplied with the SkyScan1276 contains a unique procedure for exact matching of any number of partial scans making junctions between partial scans undetectable and artifact-free.

< coronal slice through a bone with aTi implant with two washers 12mm in diameter obtained by SkyScan1276 using round (top) and helical (bottom) trajectories.

Software for Reconstruction, Visualization and Analysis

NRECON: GPU-ACCELERATED 3D RECONSTRUCTION

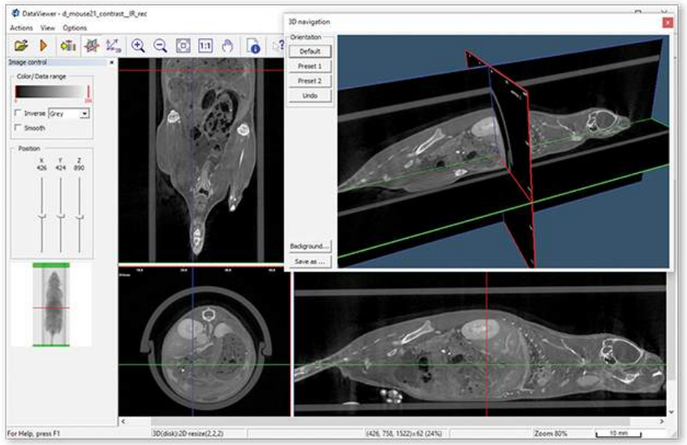


The supplied reconstruction program **NRecon** can run reconstruction for circular and spiral (helical) scans, supports beam-hardening correction, misalignment correction, ring artifact elimination, reconstruction of objects larger than field of view, automatic merging of partial scans, volume of interest reconstruction, drift compensation and many other options. The results can be saved in conventional formats, such as 16-bit TIFF, 8-bit BMP, 24-bit JPG, lossless compressed PNG as well as in DICOM format (compliant with the DICOM 3 convention). Additional **NRecon** features provide batch reconstruction of multiple datasets with individually adjusted settings, fine tuning of reconstruction parameters for best possible results, fifth order polynomial beam-hardening correction, and many other options.

The software is supplied with a choice of three reconstruction engines, which can be selected by user. The first one uses the power of all available cores of the processors (CPU) for parallel reconstruction. The second one involves the graphical card processors (GPU) to accelerate the reconstruction. Both reconstruction engines are based on the filtered back-projection algorithm. The third reconstruction engine - InstaRecon® - utilizes a unique hierarchical reconstruction algorithm, which allows more than 10 times speed-up compared to the conventional filtered back-projection algorithm.

reconstruction time for full volume / single slice	526 slices 1Kx1K from 413 projections	1052 slices 2Kx2K from 687 projections	2102 slices 4Kx4K from 1029 projections	1606 slices 8Kx8K from 2278 projections
NRecon (CPU, 3.1 GHz, 20 cores)	55s / 0.105s	9m 25s / 0.537s	1h 53m 45s / 3.25s	12h 14m 6s / 27.5s
GPURecon (NVIDIA Quadro K4200, 4 GB)	43s / 0.082s	4m 57s / 0.282s	59m 25s / 1.69s	6h 21m 33s / 14.3s
InstaRecon® (CPU, 3.1 GHz, 20 cores)	22s / 0.042s	1m 3s / 0.06s	7m 5s / 0.202s	1h 17m / 2.88s

DATA VIEWER: SLICE-BY-SLICE MOVIE, ORTHOGONAL VIRTUAL SLICES INTERSECTING AT ANY POINT



DataViewer shows reconstructed results as a slice-by-slice movie or as three orthogonal sections, intersecting at any selected point in the reconstructed space. One can rotate / reslice the reconstructed volume in any direction. Additional features include the 4th dimension for time-resolved cardiac and respiratory tomography, variable smoothing options, measuring distances in 3D with saving a table of results, and measuring intensity profiles.

DataViewer also includes automatic co-registration of several datasets in position and spatial orientation and output of differential image data.

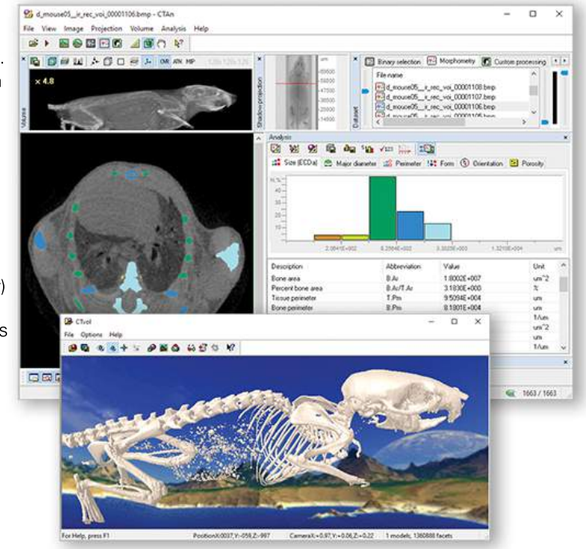
CTAN: 2D / 3D IMAGE PROCESSING AND ANALYSIS
CTVOL: REALISTIC VISUALIZATION BY SURFACE RENDERING

CT-Analyzer or **CTAn** performs accurate and detailed study of micro-CT results for morphometry and densitometry. Powerful, flexible and programmable image processing tools deliver a wide range of segmentation, enhancement and measuring functions for analysis ranging from sizes and volumes to full bone morphology and 3D distribution of trabecular thicknesses. Versatile volume of interest selection tools are included. "CT-Volume" or **CTVol** uses surface triangulated models from **CTAn** and provides a virtual 3D viewing environment, flexible and rich in features, with a wide range of options for 3D presentation of results.

The main features of **CTAn** are:

- Import of dataset in tiff, bmp, jpg, png, DICOM, etc.
- Global, Otsu, multi-level and adaptive segmentation
- Advanced region/volume of interest selection tools
- Maximum and minimum intensity projections
- Measures 3D distances and angles
- Smooth, sharpen, despeckle, Boolean operations
- Analysis of all objects within VOI in 2D, 3D
- Parameters measured (in 2D and 3D):
  - Object (tissue, separation, ...) volume, surface
  - Structure thickness, sizes of separations
  - Surface convexity index (trabecular pattern factor)
  - Euler number, eccentricity
  - Degree of anisotropy, eigenvalues, eigenvectors
  - Fractal dimension (Kolmogorov)
  - Moments of inertia (x, y, polar, product)
  - ... and many others
- Automated batch analysis
- Run user-created plug-ins

The full list of functions can be found at
bruker-microct.com/next/CTan_UserManual.pdf
bruker-microct.com/next/CTvol_UserManual.pdf



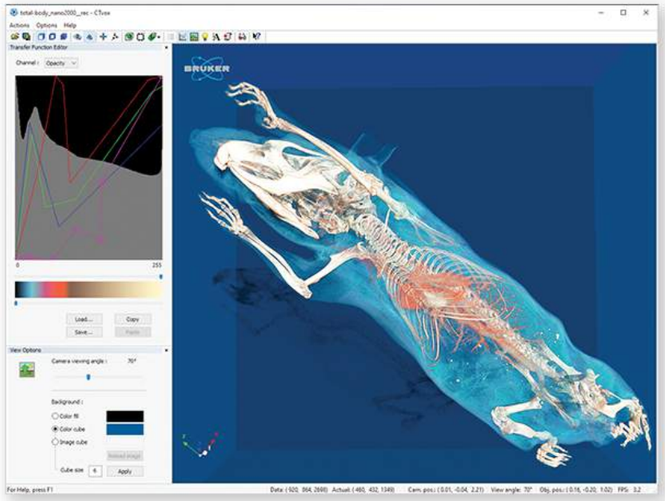
STL FILE EXPORT FOR 3D PRINTERS AND FINITE ELEMENT ANALYSIS

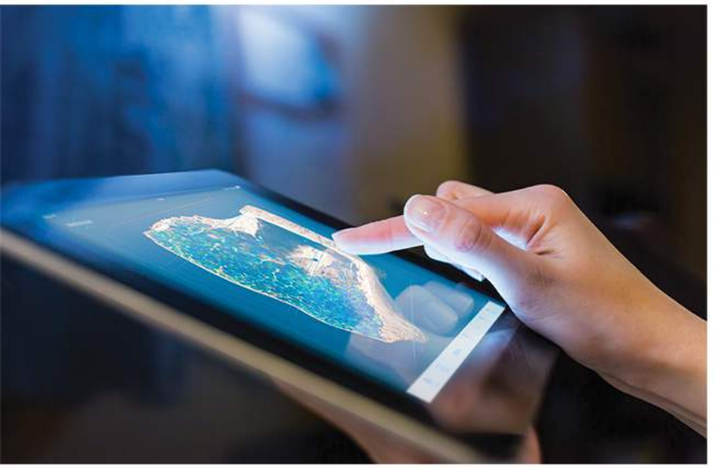
The **CTAn** / **CTVol** programs can create and visualize triangulated models of object surfaces. Such models can be saved in STL file format. The STL files are directly accepted by most 3D printers which allow the creating of a magnified physical copy of scanned objects. By selecting a volume of interest in **CTAn**, the physical model may be partially opened to give access to internal details. The STL file format is also used as input information for most FEA (Finite Element Analysis) software packages which analyze the impact of mechanical load on 3D architecture of objects.

Volume Rendering for PCs and Mobiles

CTVOX: REALISTIC VISUALIZATION BY VOLUME RENDERING

The volume rendering program **CTVox** shows reconstructed results as a 3D object with realistic textures and lighting. It has intuitive navigation and manipulation of both object and camera, a flexible clipping tool to produce cut-away views, and an interactive control to adjust transparency and colors. Adding lighting and shadowing, and adjusting material properties produce fully realistic visualization. A "flight recorder" function allows fast creation of "fly around" and "fly through" animations based on simple selection of several key frames with interpolation in between. Imaging possibilities include displaying multiple datasets obtained from different time-resolved phases, from the same or different imaging modalities or by overlapping reconstructed images with color maps of morphological parameters.





VOLUME RENDERING FOR MOBILES

The volume rendering program supplied with the system, **CTVox**, also has its mobile versions, which can be downloaded for free from the AppStore for iPhone and iPad or from Google Play for Android devices. Any 3D results obtained by the system can be sent to a mobile device for realistic visualization by real-time volume rendering, with adjustments of colors, 3D object manipulation, virtual cut, etc.

The results can be sent through a cable connection or a wireless network. The exported rendered data and color schemes are stored in the local memory of the mobile device and do not require any connection or downloading during manipulation. A large number of datasets can be loaded to the memory of a mobile device, allowing you to study reconstructed results while travelling, share them with colleagues and demonstrate them at meetings.

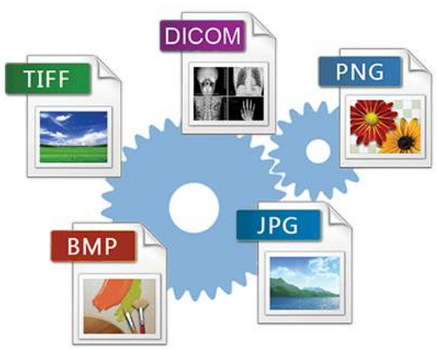
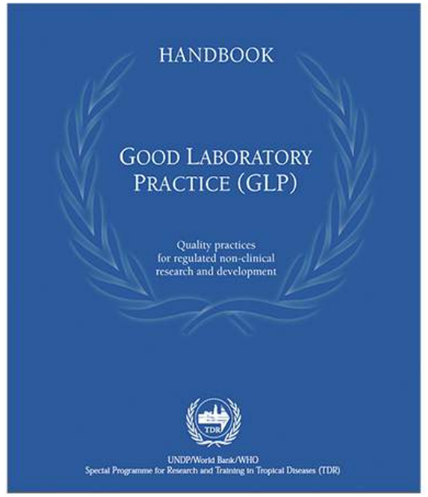


IMAGE FORMATS FOR RESULTS

All the supplied reconstruction and application software can produce and work with the DICOM format (compliant with the DICOM 3 convention), an industry standard for medical imaging instruments. The programs can also interchange results in standard Windows-readable formats, such as BMP, JPG, PNG and TIFF for images and AVI for movie files.

If necessary, images can be converted from one format to another using the supplied **Format Converter** utility. This software can convert separate image files or full dataset from one format to another with modified size and intensity scale, with renaming, resizing, rescaling and renumbering.

Comprehensive Support and Good Laboratory Practice



GOOD LABORATORY PRACTICE (GLP) SOFTWARE

The SkyScan1276 system is supplied with a GLP module, which allows administration of user rights and implementing the necessary data protection according to GLP requirements. Access to control software is protected by a user's name/password combination. Three levels of access can be granted: standard users, advanced users and supervisors. Standard user's rights allow scanning and saving data, reading results and switching scanning protocols, but do not allow erasing or modifying scanned datasets or change of scanner settings. The users with advanced access rights have access to the most system functions, and supervisors have access to full functionality of the instrument. User passwords and access rights are managed by a single system administrator.

When the GLP-module is activated, the control software duplicates every scan log-file with all scan parameters and system settings, in an encrypted copy, which cannot be directly accessed or modified. When necessary, encrypted log files can be restored to text for QA audit, to ensure the secure storing and traceability of critical scan information and allow reproduction of any scan.

TRAINING COURSES, MICRO-CT ANNUAL MEETINGS

Bruker microCT offers a combination of both system and software training that covers three major topics: image acquisition, image reconstruction and data analysis/visualization. These 5-day courses are held several times a year at the **Bruker microCT** headquarters in Belgium. They combine the theoretical background of microCT with hands-on experience. After installation of every system, new customers receive first initial training, and later advanced training either on-site or by course attendance. **Bruker microCT** also organizes an annual MicroCT meeting in the form of a 3-day scientific conference combined with training workshops. Your invitation to our next MicroCT meeting and all abstracts from presentations in previous meetings can be found at www.bruker-microct.com

'BRUKER MICRO-CT ACADEMY'

The "Bruker microCT Academy" is an efficient educational network for the hundreds of groups who are using SkyScan instruments. It includes a monthly newsletter with application and technical tips and keeps users updated on new methods, developments and company news.

Through participation in the Academy our users gain access to a database with detailed application and technical notes and can provide feedback with questions and suggestions for improvements of our instruments and software.

TECHNICAL SPECIFICATIONS

X-ray source	20-100 kV, 20 W, <5 µm spot size at 4 W	
X-ray detector	cooled CCD, 4032 x 2688 pixels, 14-bit	
Spatial resolution	2.8 µm smallest pixel size, 5-6 µm details resolved with more than 10% contrast	
Scanning space	80 mm in diameter, >300 mm in length	
Reconstructed volume (after a single scan)	up to 4000 x 4000 x 2100 or 8000 x 8000 x 1600 pixels	
Integrated physiological monitoring	real-time motion detection (5 Mp color camera), ECG, breathing detection, temperature stabilization, all signals digitized in 16bit with up to 120 samples/sec	
Radiation safety	<1 µSv/h at 10 cm from the instrument surface	
Dimensions, weight	954W x 1190D x 940H mm, 330 kg	
Power supply	100-240 V AC, 50-60 Hz, <250 W (excluding workstation)	
Control workstation	**Standard**	**Advanced**
Processors	Dual 8-core Intel XEON	Dual 10-core Intel XEON
Memory (RAM)	64 GB / 2133 MHz	128 GB / 2133 MHz
Disk space (HDD)	8 TB (2 x 4 TB, RAID0) + 512 GB Solid State Drive	12 TB (3 x 4 TB, RAID0) + 512 GB Solid State Drive
Monitor	24" UltraSharp LED LCD (1920x1200 native resolution)	

Bruker microCT is continually improving its products and reserves the right to change specifications without notice.

www.bruker.com ● **Bruker microCT**

Kartuizersweg 3,
2550 Kontich, Belgium
phone: +32 3 877 5705
fax: +32 3 877 5769

www.bruker-microct.com
info.BmCT@bruker.com
sales.BmCT@bruker.com

To connect to the **Bruker microCT** website please scan this QR-code with your mobile phone or iPad.

free QR-readers are available on the AppStore