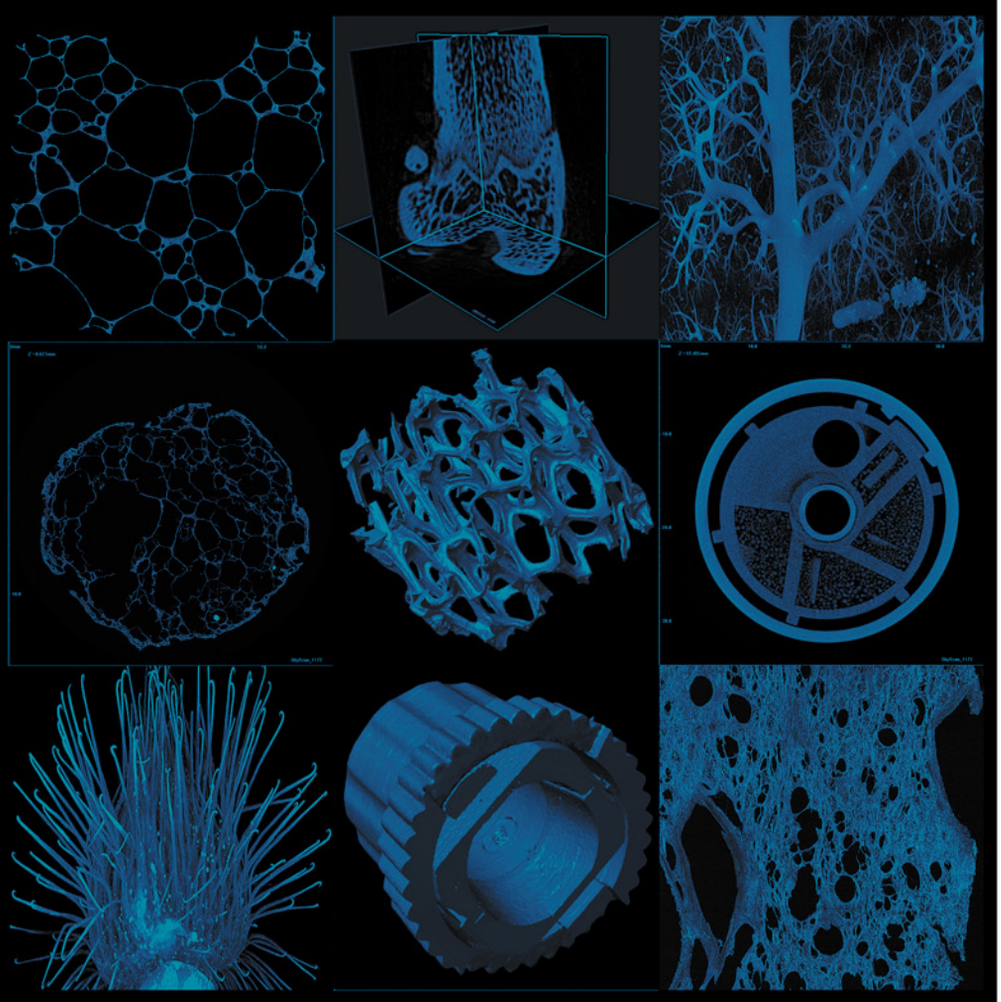
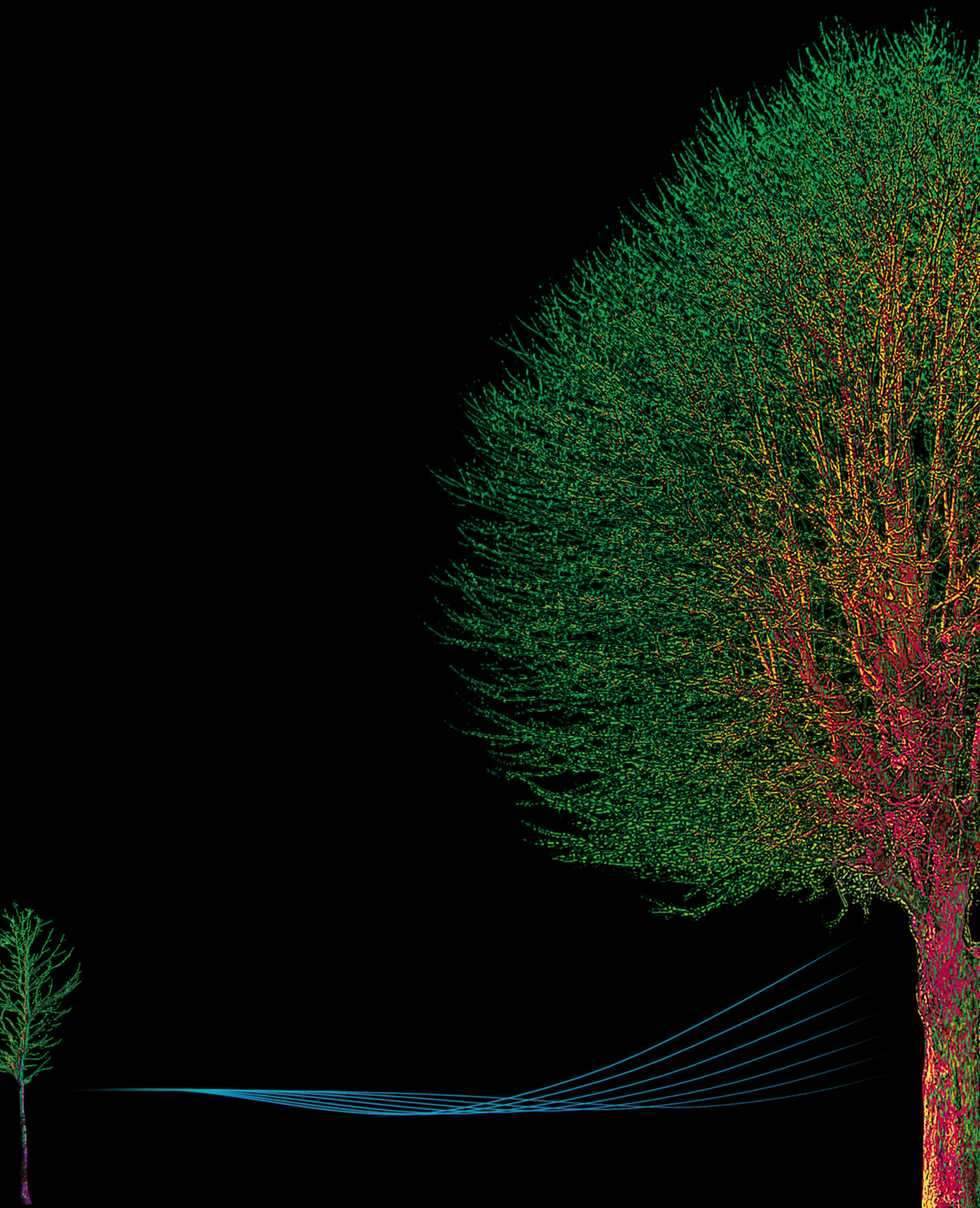
SKYSCAN

X-RAY MICROTOMOGRAPHY
X-RAY NANOTOMOGRAPHY
NON-DESTRUCTIVE TESTING
SMALL ANIMAL IMAGING
2D / 3D IMAGE ANALYSIS

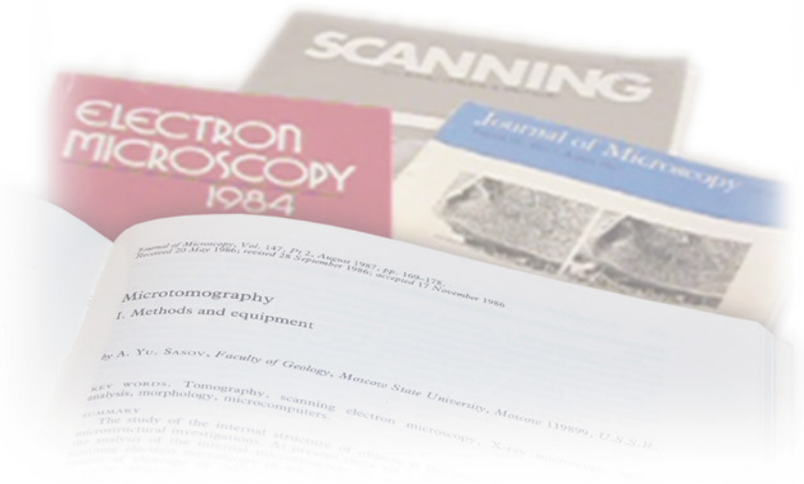


SkyScan: micro-CT from basics to perfection



Micro computed tomography or "micro-CT" is x-ray imaging in 3D, by the same method used in hospital CT (or "CAT") scans, but on a small scale with massively increased resolution. It really represents 3D microscopy, where very fine scale internal structure of objects is imaged non-destructively. No sample preparation, no staining, no thin slicing - a single scan will image your sample's complete internal 3D structure at high resolution, plus you get your intact sample back at the end!

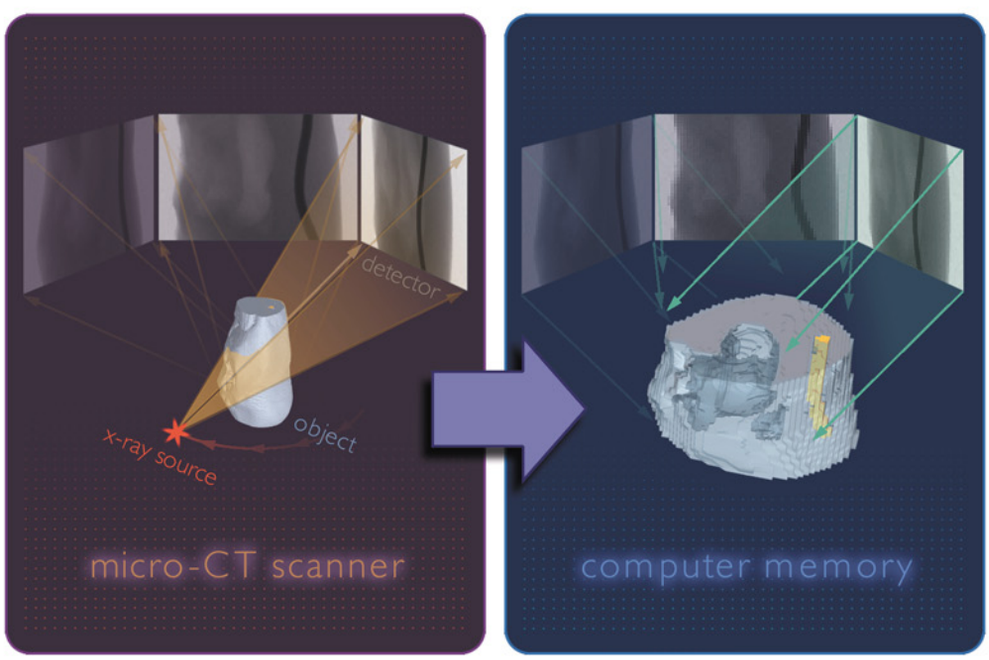
3D X-RAY MICROSCOPY



SkyScan can genuinely claim to be at the fore-front of the development of high performance micro-CT technology. Our research and development of 3D x-ray microscopy started in the early 1980s. This led to the first micro-CT imaging results being obtained in 1983-1987 and published in scientific journals and international conferences proceedings. Building on this early work, SkyScan was founded in 1996, and within a year we were manufacturing a commercially available micro-CT scanner with spatial resolution in the micron range. In 2001 we produced the first high-resolution in vivo micro-CT scanner for small animal imaging. And in 2005 SkyScan became the world's only supplier of a laboratory nano-CT scanner with submicron spatial resolution.

MICRO-CT

How does micro-CT work? A micro-focus x-ray source illuminates the object and a planar x-ray detector collects magnified projection images. Based on hundreds of angular views acquired while the object rotates, a computer synthesizes a stack of virtual cross section slices through the object. You can then scroll through the cross sections, interpolating sections along different planes, to inspect the internal structure. Selecting simple or complex volumes of interest, you can measure 3D morphometric parameters and create realistic visual models for virtual travel within the object.



SKYSCAN

SkyScan is a fast growing company and one of the world's leading producers of micro-CT systems for a wide range of applications. SkyScan aims to bring to customers the newest technology, the best instrument quality and the highest level of support. Responding to demand from the growing community of micro-CT users, we are continually active in research and development into new methods for non-destructive 3D microscopy

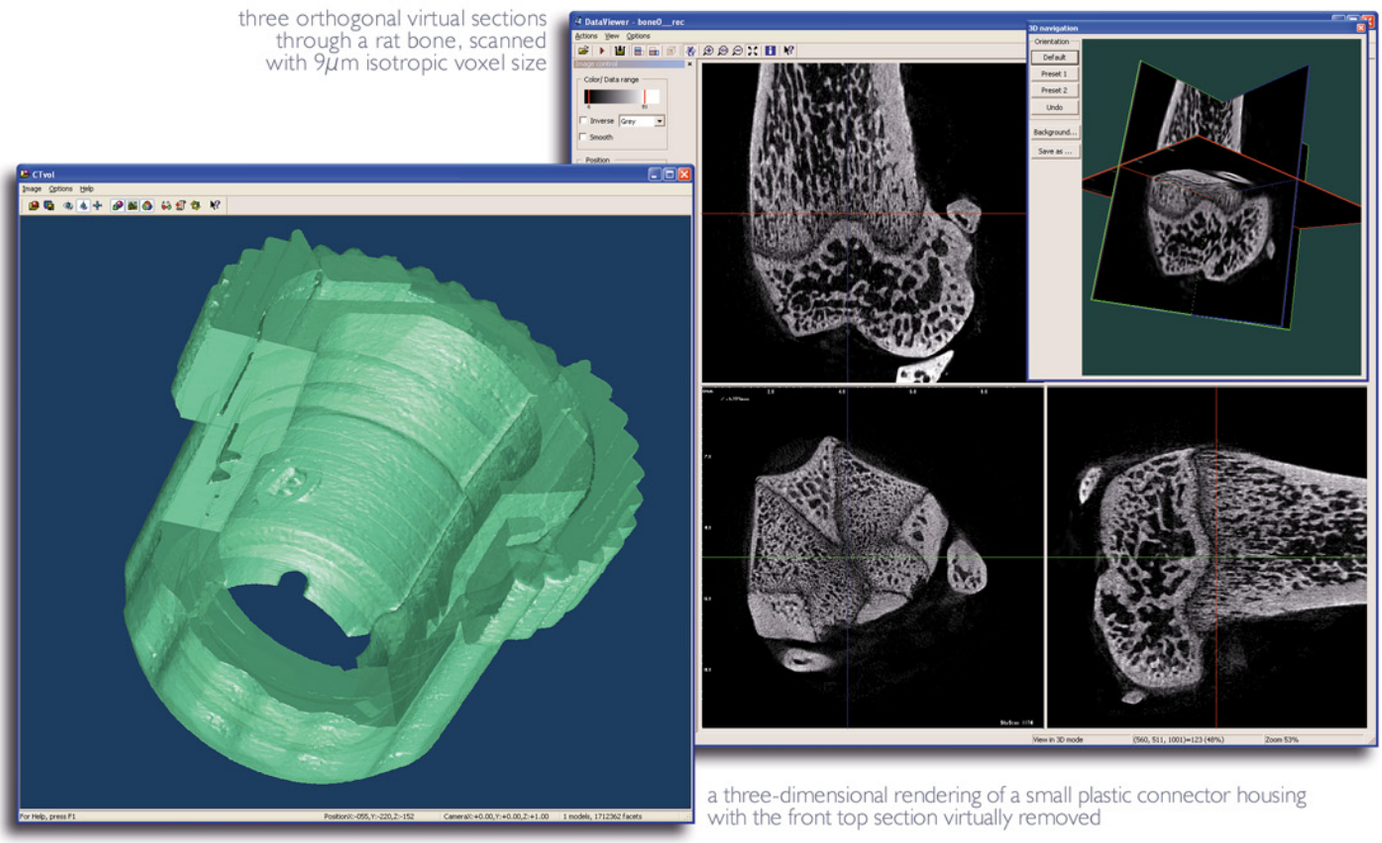
SkyScan1174 compact micro-CT

The SkyScan 1174 is a compact, cost-effective micro-CT scanner with variable magnification. Fast scanning, straightforward control, small footprint and maintenance-free operation make the 1174 an ideal solution for scientific research, quality control and industrial applications.

FEATURES

This scanner uses an X-ray source with adjustable voltage and a range of filters for versatile adaptation to different object densities. A sensitive 1.3 megapixel X-ray camera allows scanning of your whole sample volume in several minutes. Variable magnification (6-30 μm pixel size) is combined with object positioning for easy selection of the object part to be scanned. The scanner can run from any desktop or portable computer, requiring just one USB (or serial) port and a FireWire (IEEE1394) input. The full range of SkyScan software is supplied, including fast volumetric reconstruction, software for 2D / 3D quantitative analysis and for realistic 3D visualization.

three orthogonal virtual sections through a rat bone, scanned with 9μm isotropic voxel size



a three-dimensional rendering of a small plastic connector housing with the front top section virtually removed

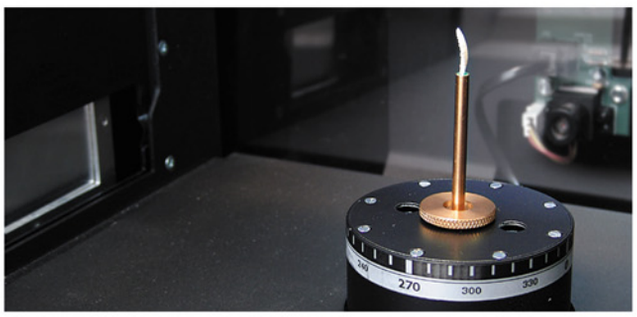
for more examples visit www.skyscan.be

SPECIFICATIONS

X-ray source ..... 20-50kV, 40W maximum power, filter holder for energy selection
X-ray detector ..... 1.3Mp CCD coupled to scintillator by lens with 1:6 zoom range
Spatial resolution ..... 6...30 μm pixel size, approximately 12μm low-contrast resolution
Object size ..... 5 - 30mm in diameter, 50mm in length (50mm vertical travel)
Reconstruction ..... single PC or cluster volumetric reconstruction (Feldkamp algorithm)
Optional stages ..... micro-positioning, cooling, compression / tension -> see page14
Radiation safety ..... < 1μSv / h at any point on the instrument surface
A range of sample holders is available

Several special purpose stages can be used for the 1172 and 1174 scanners. The stages are easily installed in place of the standard specimen holder, and take control signals and power from a small plug at the base of the sample stage mount. These special stages are controlled by software independent of the main scanner control program.

MICRO-POSITIONING

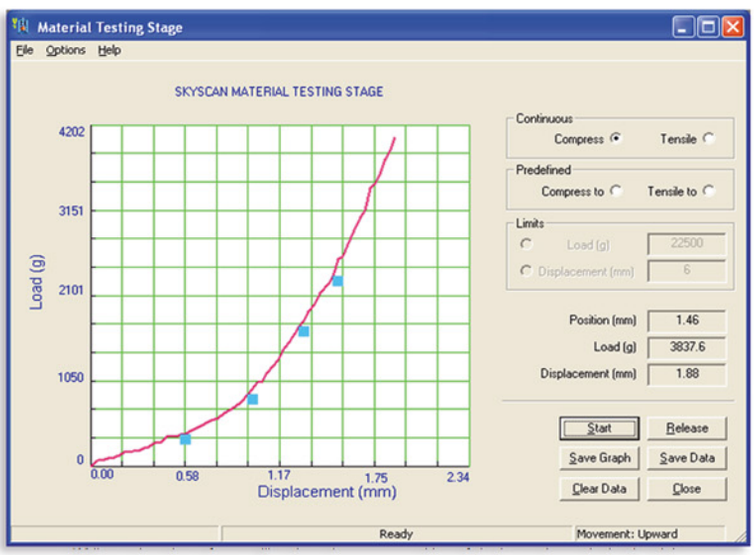


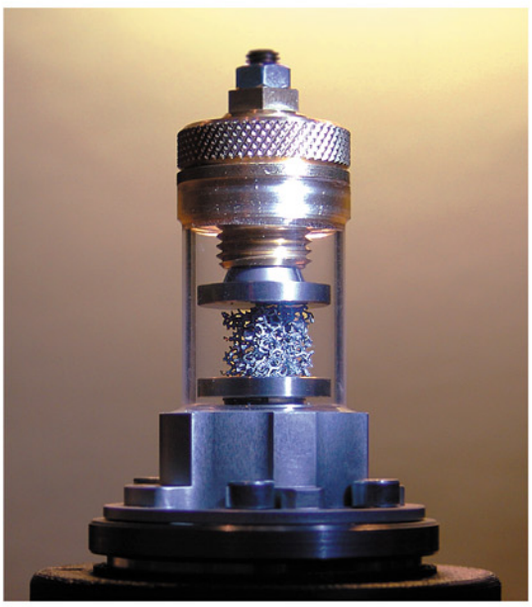
The micro-positioning stage helps to achieve exact positioning of small objects in the middle of the scanning field. Precise object centering improves all aspects of scan quality, enabling maximum magnification to be achieved and optimizing scan speed. This positioning stage has 5mm travel in the X and Y directions, and axial positioning is attained in a straightforward, user-friendly procedure, by reference to projection images.

MATERIAL TESTING

The material property testing stage applies controlled compression or tension to an object, while having a design which allows the tomographic scanning of the object. The loading curve is displayed on-screen in real time. Your object can be held under specific loading for micro-CT scanning.

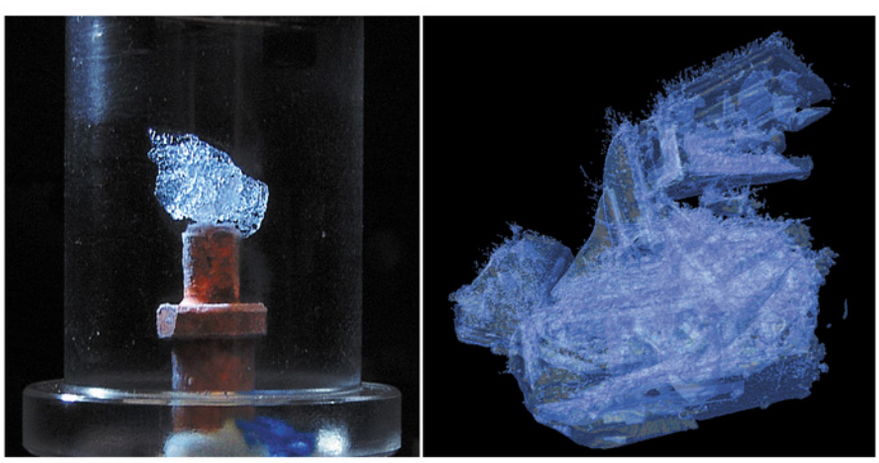
Maximum object diameter: 20mm
Maximum object length: compression - 23mm, tension - 18mm
Travel: 5.5mm
Maximum compression and tension force: 42, 210 or 420N





The software module for the material testing stage controls the stage in all modes, indicates displacement and force, shows the loading curve, marks selected points on the plot and saves the plot as a BMP-image. Numerical output of the loading data is also provided. During testing the operator can change the direction of loading for dynamic and cyclic tests.

COOLING



The cooling stage keeps an object at a cooler-than-ambient or sub-zero temperature during imaging and micro-CT scanning. It contains a two-stage solid-state Peltier cooling system which keeps object temperature at up to 50°C below ambient temperature. An internal microprocessor and a precision temperature sensor provide feedback to the stage control program for temperature stabilization during scanning at a pre-selected value, with 0.5°C accuracy.

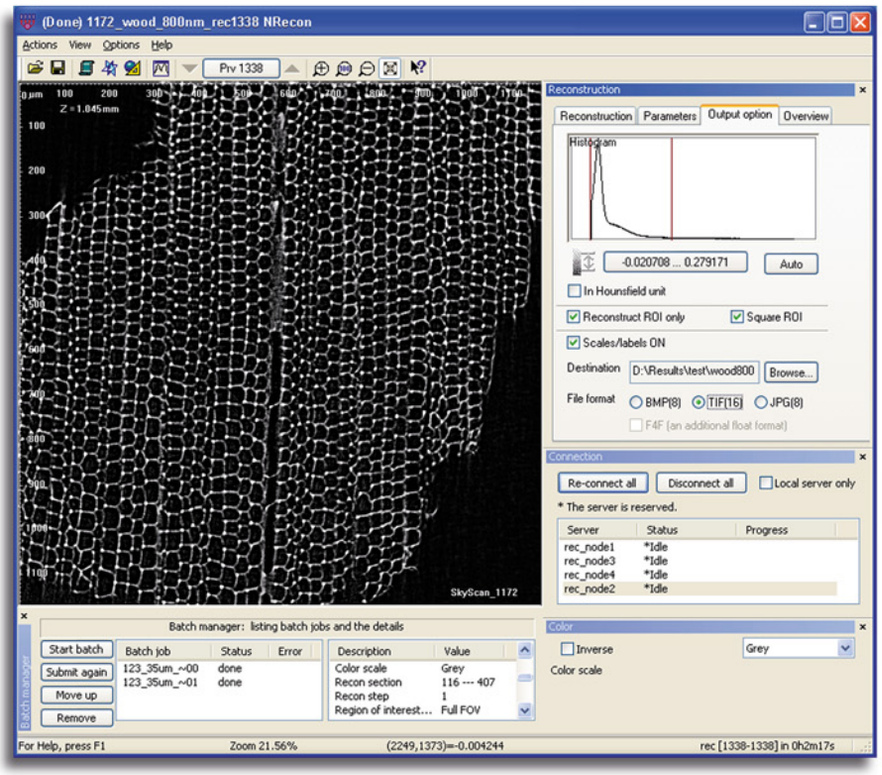
left - a piece of ice inside the cooling stage;
right - a 3D rendering of an ice crystal scanned at -22°C, 5μm voxel size.

Reconstruction and visualization programs

SkyScan supplies all micro-CT scanners with high-speed volumetric reconstruction software, which can be optionally accelerated by a cluster of several computers connected by a gigabit network. The results of 3D reconstruction can be displayed by slice-by-slice scrolling, by three orthogonal sections through any internal point of the reconstructed space, or by conversion to realistic 3D models.

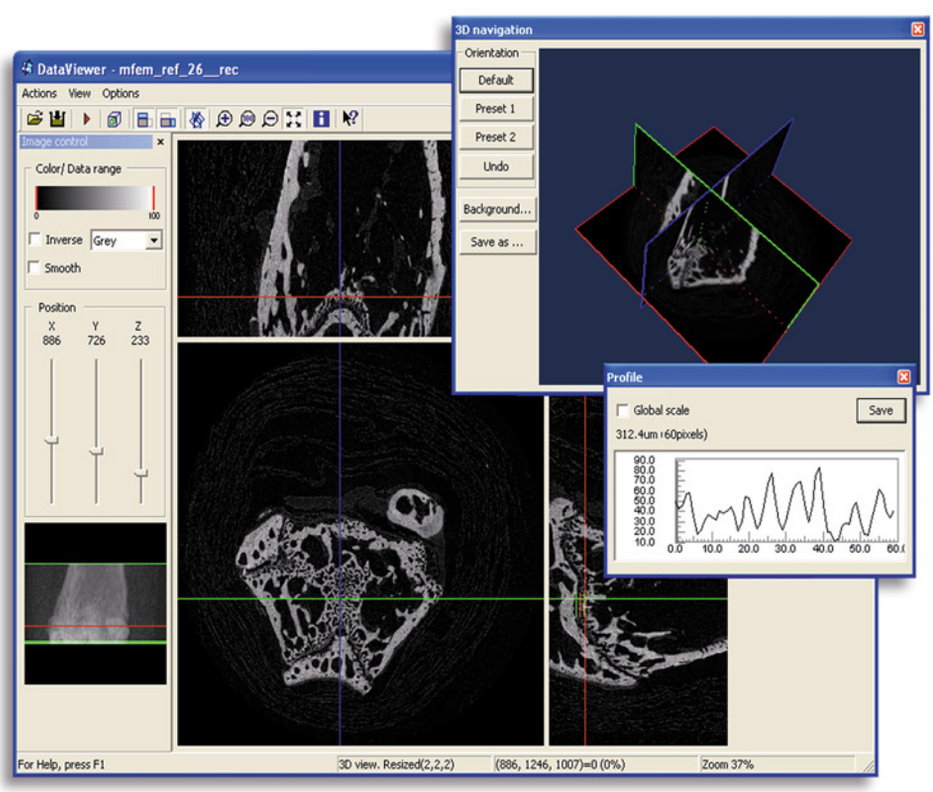
VOLUMETRIC RECONSTRUCTION

SkyScan's volumetric reconstruction software "NRecon" uses the set of acquired angular projections to create a set of cross section slices through the object. The program uses a modified Feldkamp algorithm with automatic adaptation to the scan geometry in each micro-CT scanner. Reconstructed slices can be saved in BMP, TIFF, JPG or numerical data format. The program can run on one PC or distribute the reconstruction across a cluster of several networked PCs working in parallel to achieve exceptional speed.
NRecon measures and adapts to differences in computer performance and network connection for equitable job distribution. Reconstruction includes beam-hardening correction, alignment optimization, ring artifact correction, reconstruction in a restricted volume of interest, reconstruction of objects wider than the field of view, external and internal calibration into Hounsfield units and interactive density window selection. NRecon accepts large format angular projection images to reconstruct cross section images with up to 8000x8000 pixels. User-friendly batch processing allows many reconstruction jobs with different settings to be run sequentially without operator input. Refer to SkyScan website for reconstruction speed.



A screenshot of NRecon with a reconstructed cross section of a wood sample scanned by the SkyScan 1172, with 0.8μm voxel size.

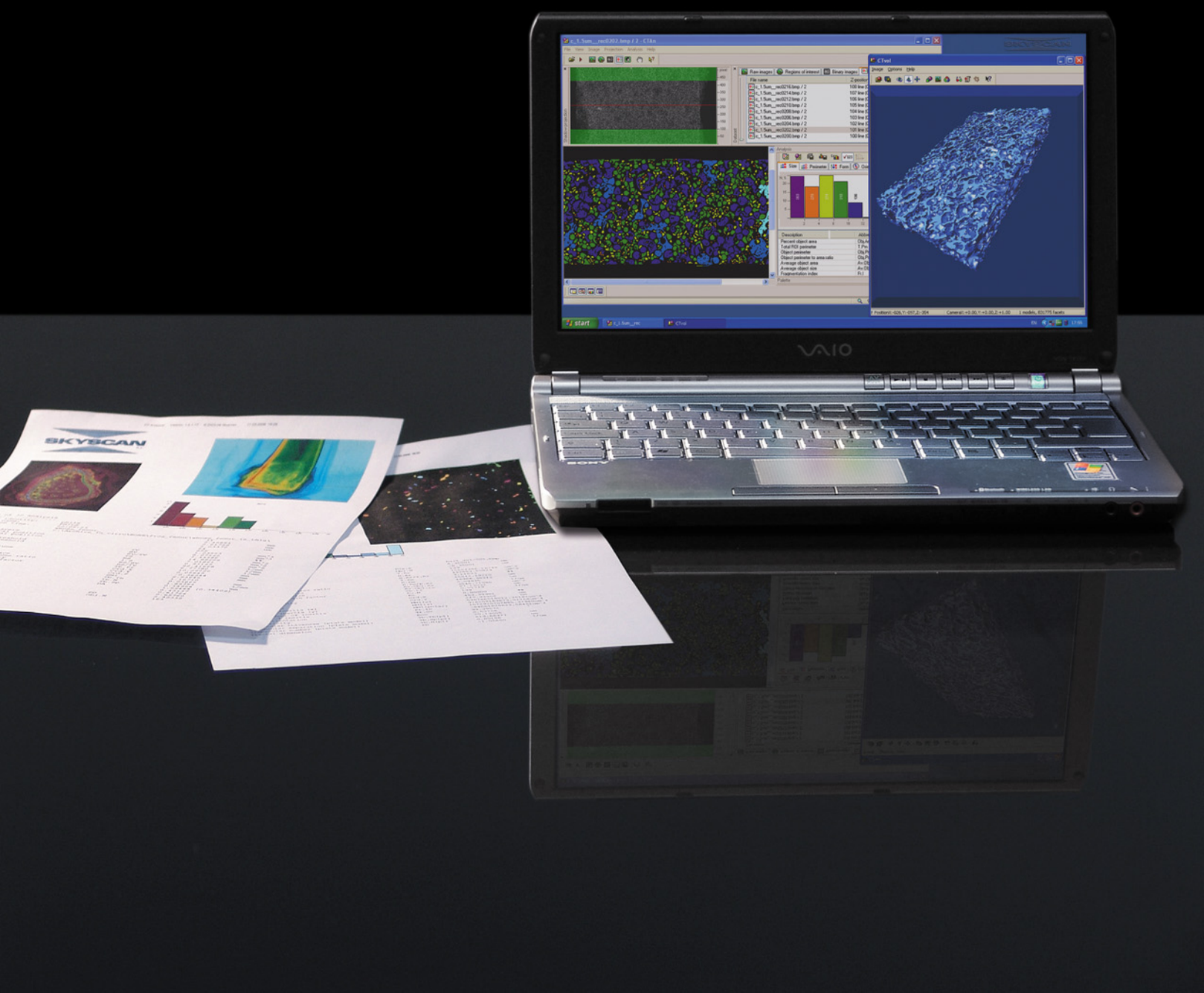
VISUALIZATION, FORMAT CONVERSION



A screenshot from a bone dataset (SkyScan 1172) viewed by the Data Viewer utility.

The reconstructed set of slices can be flexibly viewed in SkyScan's "Data Viewer" program. Images are displayed as a slice-by-slice movie or as three orthogonal sections, centered at any selected point inside the reconstructed space. Possibility to rotate the transversal slice and view orthogonal sections at this position. Data Viewer also has a viewing mode with three intersecting orthogonal sections, which can be turned and each intersecting slice independently moved by simple mouse control. Additional features include 4th dimension for compression/tension and time-resolved tomography, variable smoothing, saving interpolated datasets in saggital or coronal section, measuring and saving distances and intensity profiles. The format converter utility "T-conv" converts between TIFF, BMP and JPEG files with adjustment of colour palette, inversion, renaming, resizing and combining of datasets. A utility is also provided for conversion to DICOM 3 format.

Software for analysis and realistic visualization



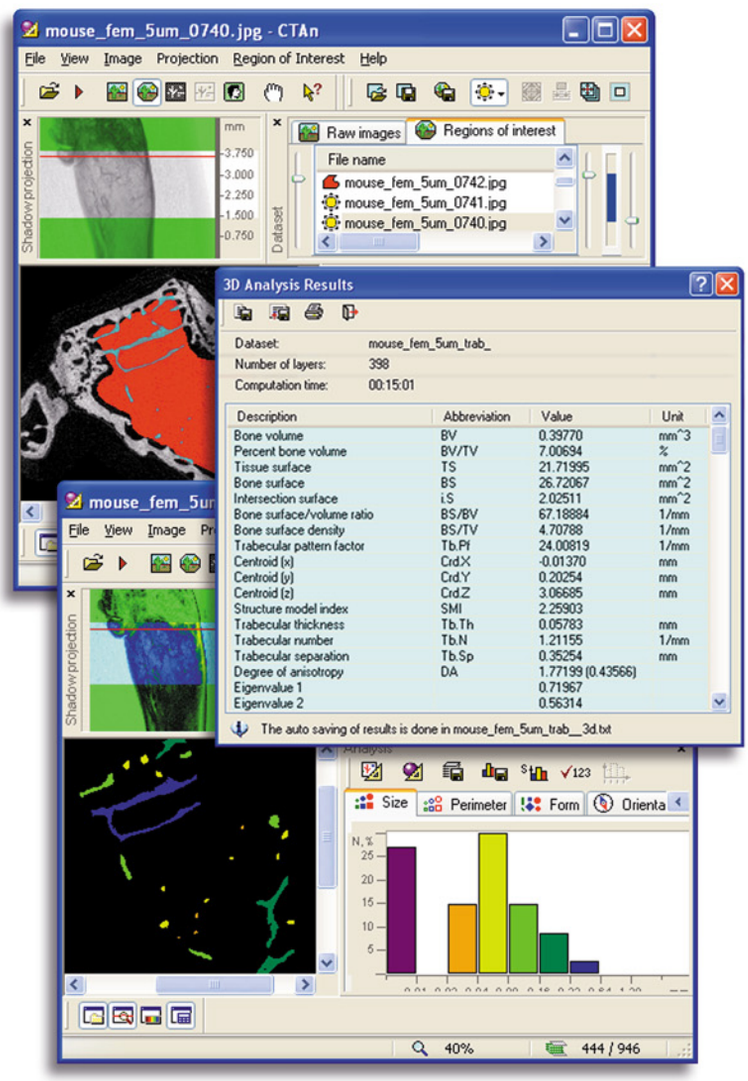
All SkyScan scanners are equipped with a software package for complete 2D and 3D quantitative analysis of reconstructed volumes from micro-CT scans, the program "CT-analyser", and software for realistic 3D visualization of scanned objects, the "CT-volume" program. These programs can run on the supplied workstation or on any of your laboratory's desktop or notebook computers.

2D / 3D IMAGE ANALYSIS

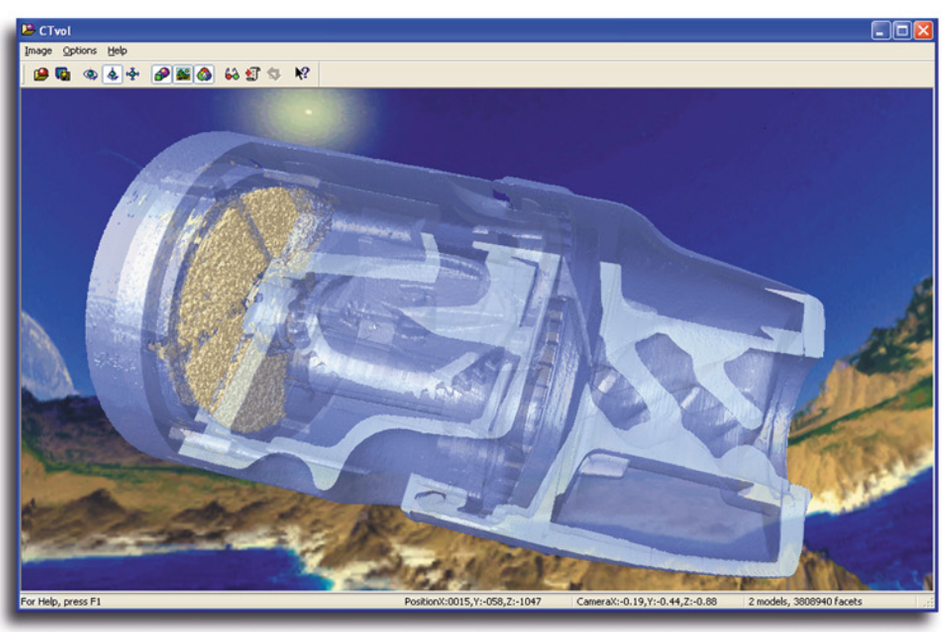
SkyScan "CT-analyser" allows accurate and detailed study of micro-CT datasets for morphometry and densitometry. Powerful, flexible and programmable image processing tools allow a wide range of segmentation, image enhancement and measurement functions for analyses ranging from porosity to contact surface around high-density insertions to complex architectures. Versatile volume of interest selection tools are included.

Main software features are:

- o Import and output of dataset in tiff, bmp, jpg
- o Angular resampling of datasets to any solid angle
- o Advanced region/volume of interest selection tools
- o Measures 3D distances and angles
- o Creates maximum intensity projection (MIP) images
- o Calibrates density as HU, BMD or attenuation coefficient
- o Smooth, despeckle, morphological operations etc.
- o Programmable stacking of functions ("scripting")
- o Analysis of integrated structures within VOI in 2D, 3D
- o Analysis of all individual objects within ROI/VOI in 2D, 3D
- o Parameters measured (including 2D and 3D):
  - o Object (pore, particle, etc.) or "bone" volume
  - o Object or "bone" surface
  - o Structure or "trabecular" thickness
  - o Structure or "trabecular" separation, number
  - o Structure Model Index (SMI)
  - o Fragmentation index or "trabecular pattern factor"
  - o Euler number
  - o Degree of anisotropy by MIL, (+eigenvalues, eigenvectors)
  - o Fractal dimension (Kolmogorov)
  - o Moments of inertia (x, y, polar, product), eccentricity
  - o Detailed analysis of porosity
- o Automated batch analysis
- o Measurements validated by real and virtual phantoms
- o Creates 3D models by several rendering algorithms



REALISTIC 3D VISUALIZATION



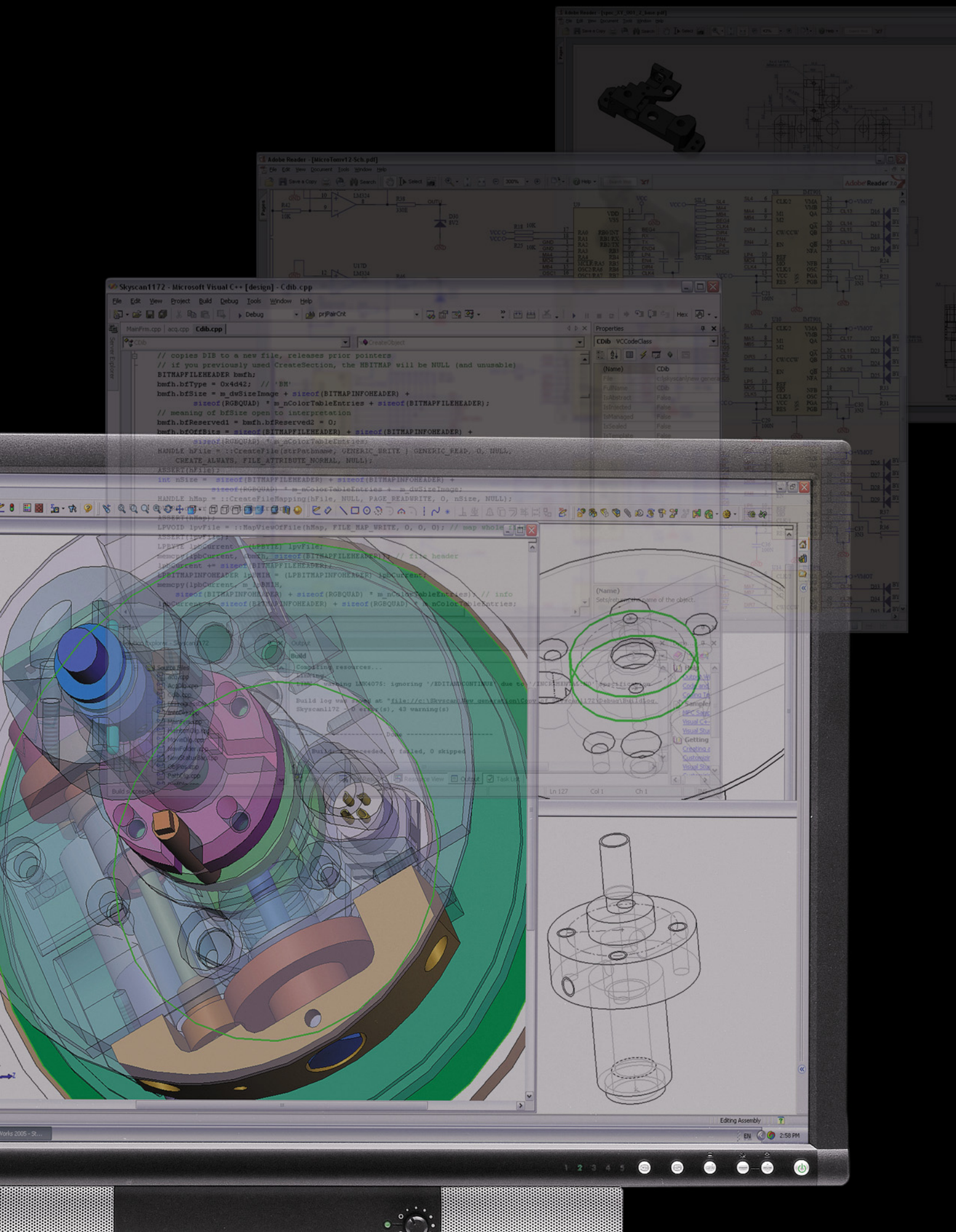
A 3D rendering of an inhaler device comprising a plastic body (blue) filled by powder (yellow) with the front top part virtually removed

"CT-volume" provides a virtual 3D viewing environment, flexible and rich in features, to give you a wide range of options for 3D presentation of micro-CT results.

"CT-volume" allows:

- o Movement and rotation of single and multiple object models
- o Selection of background colour including scenery
- o Selection of viewing angle
- o Model movements by free mouse operation or selected increments
- o Control of object texture, colour, lighting and transparency
- o Cut models along a selected plane to reveal internal structure
- o Resampling / interpolation of a dataset in any planar 3D orientation
- o Semi-automated creation of animated "movies"

Quality certification, instrument improvements



Highly skilled groups at SkyScan are continually performing quality checks, improving the design of the scanners and optimizing the hard- and software in order to reach the best possible scan results. Before shipment to the customers, all instruments built by SkyScan are individually adjusted, tested and certified.

CE CERTIFICATION

DECLARATION OF CONFORMITY

We,

SKYSCAN N.V.
Kartuizersweg 3B
2550 KONTICH
BELGIUM

declare, solely under own responsibility, that the product

SKYSCAN, model 1172

mentioned in this declaration,

complies with the following standards

IEC 61326 : 2002
IEC 61010-1 : 2001 (2nd Edition); EN 61010-1 : 2001(2nd Edition)

as has been laid down in reports and certificate

EMC/COC/B3/2005, ELC/EMC/613, 577077/01

Reference: EMC/COC/B3/2005

CERTIFICATE OF CONFORMITY

Product	Analysis equipment
Tested by request of	Skyscan N.V. Vluchtenburgstraat, 3C 2630 AARTSELAAR Belgium
Manufactured at (name and place)	Skyscan N.V. Vluchtenburgstraat, 3C 2630 AARTSELAAR Belgium
Trade mark (if any)	SKYSCAN
Model/Type Ref	1172

IEC 61326:2002

shown in the test report(s): ELC/EMC/613

a Certificate of Conformity is the result of testing a sample of the product submitted, in ordance with the provisions of the relevant specific standard. It does not imply an assessment of whole production. Conformity of the produced products with the specimen tested remains on the responsibility of the manufacturer.

Brussels, 28/11/2005

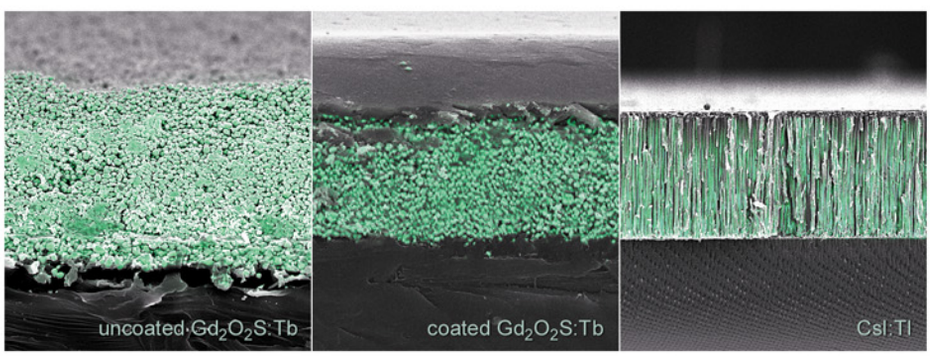
R. MAQUESTIAU

Certification Manager

All the SkyScan scanners are CE-marked. The procedure to get this CE-marking is performed by SGS CEBEC-Belgium. Other certification, like FDA-proofs and ASTM-certification are done by various test-lab's worldwide.

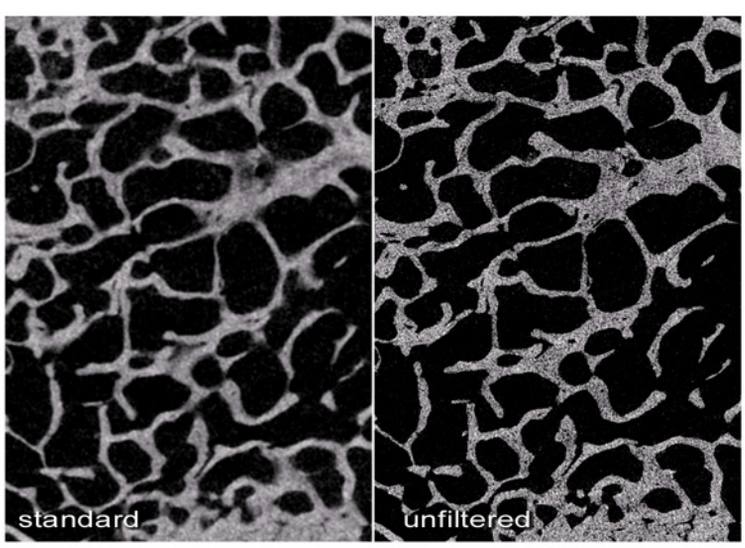
SCINTILLATOR OPTIMISATION

The scintillator layer, which converts x-rays into visible light inside x-ray detectors, defines the key performance parameters of micro-CT, such as scanning speed and spatial resolution. SkyScan is working on optimising scintillator coatings using standard imaging by scanning electron microscopy in combination with local light emission mapping, to define the optimal thickness, grain size and packing of scintillator for each particular micro-CT instrument.



SEM images of different scintillator layers with color highlighting of local emission.

"UNFILTERED" MICRO-CT

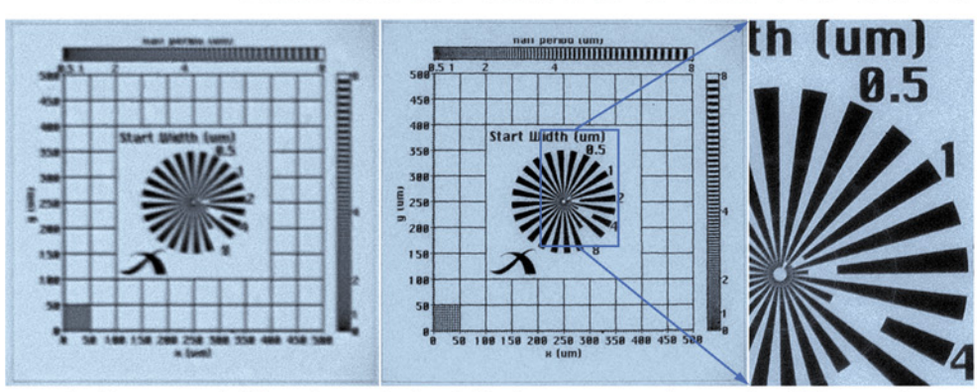


All commercially available micro-CT scanners use various ways of filtering projection images during acquisition, to improve signal to noise ratio and to avoid bright dots from direct hits on the detector by x-ray photons, which create lines across reconstructed slices. Such filtering always reduces the contrast of small, thin and low-density details in the reconstructed cross sections, increasing uncertainty in subsequent image thresholding and numerical analysis. SkyScan has invented a new acquisition technique to avoid any filtering during collection of shadow projections. In such UNFILTERED TOMOGRAPHY, the filtering process is replaced by an intelligent comparison of sequential images to extract the useful part and reject noise, while keeping information on small object details down to one voxel in size in the reconstructed image slices.

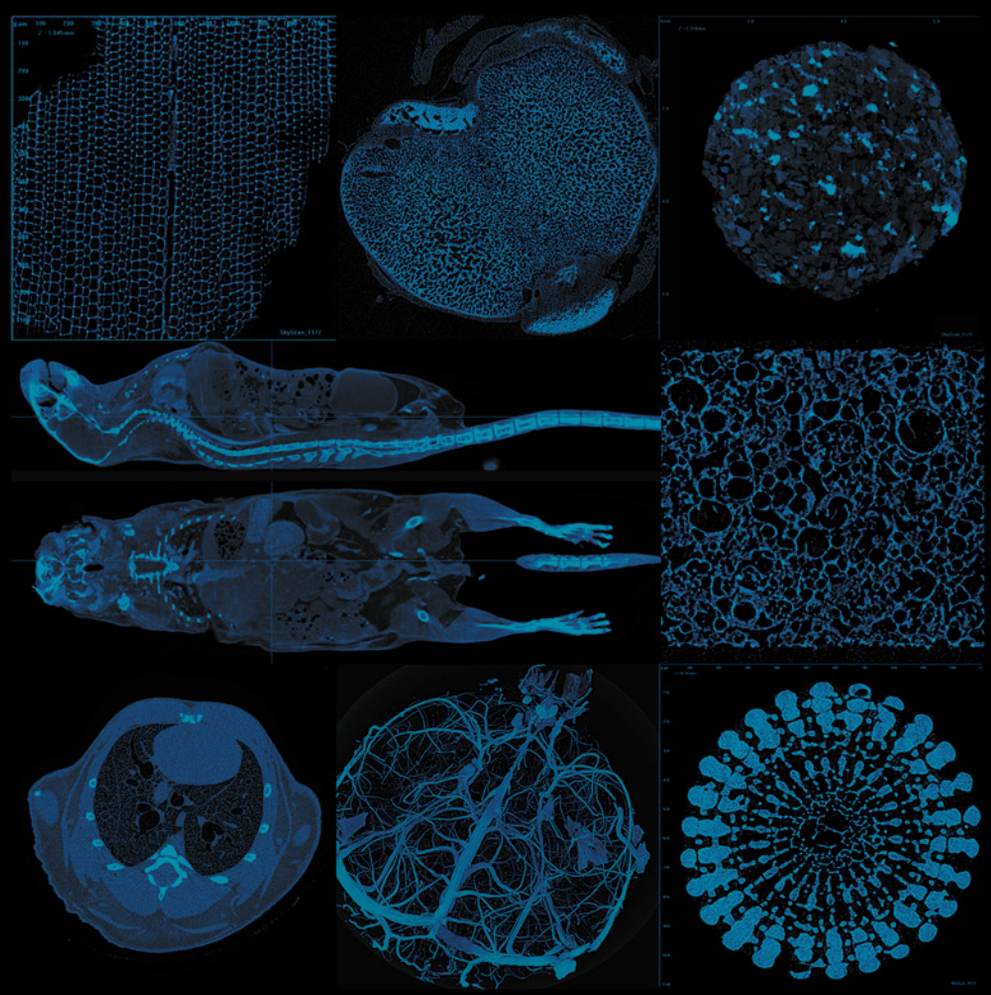
Reconstruction of the structure inside bone trabeculae using standard and newly developed acquisition modes.

RESOLUTION IMPROVEMENT

The spatial resolution of all micro-CT instruments is dependent on the spot size in the X-ray source. Switching from micro-CT to nano-CT instruments requires special X-ray sources with an optimal thickness and composition in the X-ray target for the best possible spot size and reasonable flux from the source.



X-ray source resolution measurements by a standard "star pattern": left - an image obtained with the x-ray source from a micro-CT system shows a spot size around 4μm; central and right - an image from the source used in nano-CT with a specially selected target shows resolution better than 0.5μm.



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