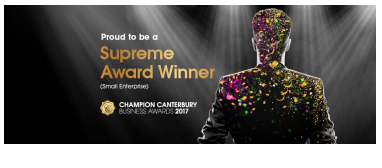
mars

Preclinical Spectral CT System

Spectral molecular imaging with histology level information

MARS small animal spectral CT harnesses Medipix3RX, the world's most advanced energy resolving photon-counting detector. The scanner is fully self contained & fully automated for biomedical research.



NEW ZEALAND INNOVATION AWARDS® 2017 | WINNER

CERN technology

MARS Bioimaging has exclusive rights for Medipix3 developed at CERN in the field of small animal and human CT

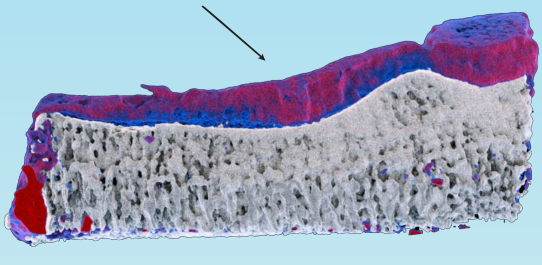
MARS scanners generate multi-energy images with high spectral and high spatial resolution and with low noise. This allows functional imaging by simultaneously identifying and quantifying various components of soft tissues, bone, cartilage as well as exogenously administered contrast agents, nanoparticles, and pharmaceuticals in a single scan.

The specimen to be imaged remains stable on a translatable bed with rotating gantry that houses an x-ray tube and a MARS camera. With current MARS scanners, specimens up to 100mm diameter and 280mm in length can be imaged.

A MARS camera is an assembly of multiple photon counting, energy resolving detectors, each comprising a Medipix3RX CMOS ASIC, bump-bonded onto the high-Z semi-conductor sensor crystal of doped cadmium zinc telluride (CdZnTe or CZT). CZT has a high quantum detection efficiency within the human diagnostic energy range (30-120 keV). This makes it highly suitable for pre-clinical/clinical spectral imaging.

Each CZT-Medipix3RX detector is an array of 128 x 128 pixels, each 110 x110 μm^2, giving an active area of 14.1 x 14.1 mm^2. The energy-resolving photon counting detectors are the unique, patented technology that enable spectral imaging in the human diagnostic energy range.

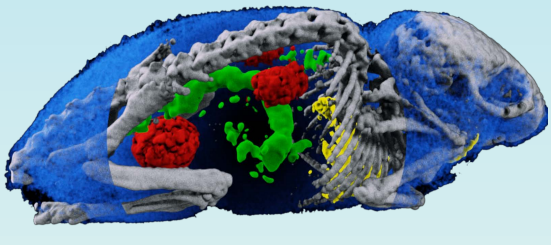
Medipix3RX has a “charge summing mode” that enables more accurate energy measurement, and a super-pixel mode enabling the collection of images using up to 8 energy bins simultaneously.



Osteoarthritis biochemistry

Measurement of cartilage health in excised human tibial cartilage

The early biochemical changes of osteoarthritis can be quantified

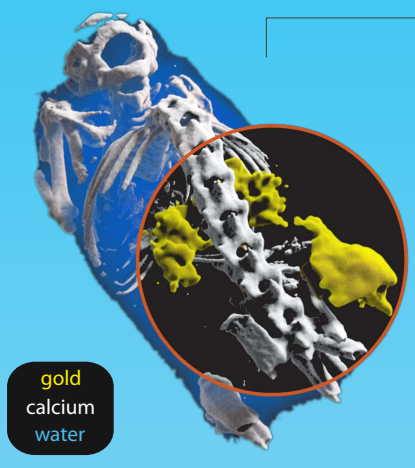


gold iodine gadolinium calcium water

Multiple targeted agents

Many agents have their own spectral signatures.

The MARS system can measure multiple targeting agents simultaneously.

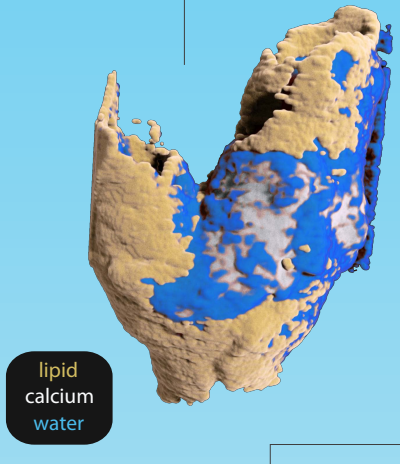


Cancer imaging

Better characterisation and better drug delivery.

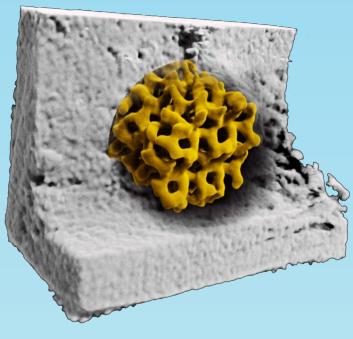
The technology opens the door to targeted imaging probes on CT.

Left: gold nano-probes within a murine model of lung cancer with a 2D magic lens used to enhance the view of the region of interest.



Spectral imaging of atherosclerosis

Histological scale imaging of the components of a plaque, including its lipid-rich core and micro-calcifications.

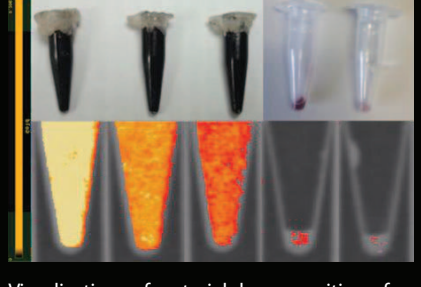


Reducing metal artifacts in bone

Streak and beam hardening artifacts caused by metal can be removed.

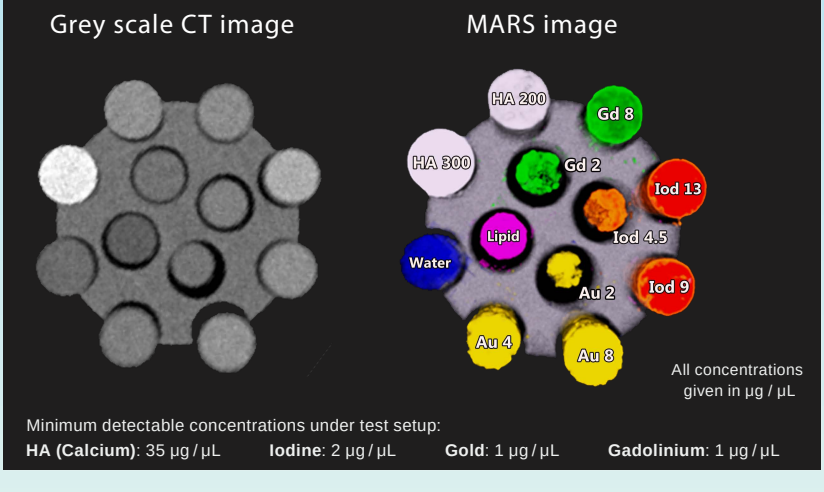
This enables clear visualisation of the bone-metal interface.

Functionalized nanoparticles



Visualizations of material decomposition of (a) AuNPs 8mg/mL, (b) AuNPs 4mg/mL, (c) AuNPs 2mg/mL, (d) SK-BR3 cells incubated in functionalised AuNPs with Herceptin and (e) SK-BR3 cells incubated in functionalized AuNPs with Rituximab.

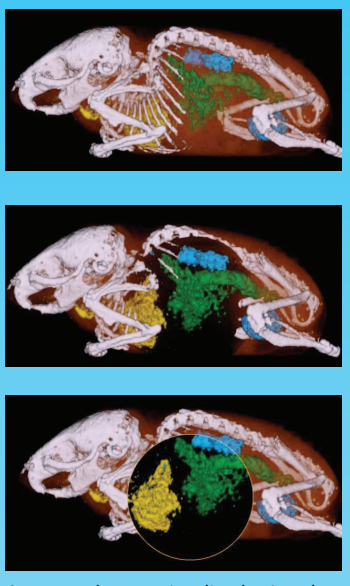
MARS material quantification



Minimum detectable concentrations under test setup:
HA (Calcium): 35 µg / µL **Iodine**: 2 µg / µL **Gold**: 1 µg / µL **Gadolinium**: 1 µg / µL

MARS scanner specifications

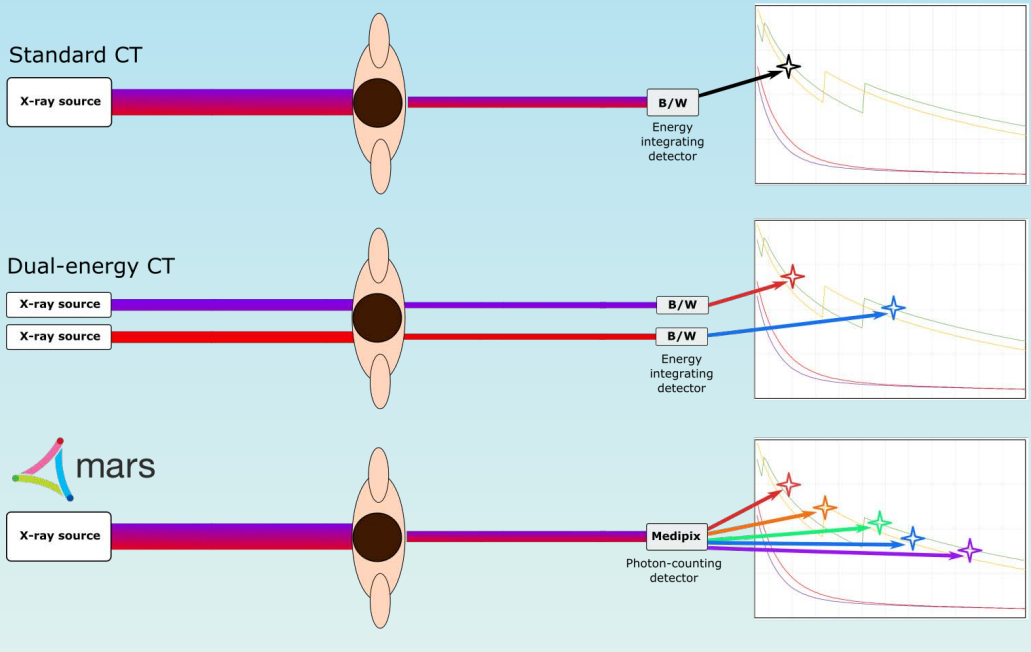
- Spectral range: 10-120 keV
- Sample bed ready for gas lines, monitoring inputs and temperature sensors
- Variable source and detector distances giving variable magnification
- Molecular image visualisation and analysis software
- MARS Vision workstation with HP zVR 3D interactive virtual reality system
- Radiation dose similar to conventional CT (20-80 mGy)
- LED illumination of the sample. HD webcam for real-time sample monitoring
- Fully x-ray shielded cabinet on industrial, locking caster wheels
- Reconstruction, processing and PACS server rack mounted inside scanner
- Data acquired and stored in a standard medical format (DICOM)
- Adjustable filters, and x, y automatic tracking collimators
- Small footprint - fits through most doorways: 75 x 140 x 117 cm, 520 kg
- Scan time: 8 minutes for a sample with 30 mm diameter and 15 mm length



A mouse dataset visualised using the MARS Vision visualisation software.

- X-ray source: SourceRay SB-120-350 (glass window)
  - o maintenance free -air cooled, shielded and sealed unit
  - o tube voltage: 60 -h 120 kVp (calibrated range)
  - o tube current: 10 - 350 µA
  - o focal spot size 50 µm (nominal)
  - o up to 39 W continuous power
  - o inherent filtration: 1.8mm Al equivalent
- MARS camera
  - o n x1 array of MARS CZT-Medipix3RX hybrid detectors
  - o 2 mm doped CdZnTe conversion material
  - o 128 x 128 x n pixels (n = number of detectors)
  - o Pixel size: 110 x 110 µm^2
  - o Spectral mode: simultaneous acquisition of 8 energy bins
  - o Charge summing mode – patented ASIC logic for greater energy resolution
  - o Energy range selectable from 10 – 120 keV
  - o 1 Gb Ethernet readout
- Geometry
  - o Scan diameter: adjustable range 20 - 100 mm
  - o Scan length: 10 to 280 mm
  - o Nominal voxel size: 30 - 100 µm (user selectable)
  - o Continuous rotation
  - o Scan modes: circular, helical
- Sample bed and sample holders
  - o Mount plate system for quick and flexible mounting of samples
  - o Mount plate blanks and a range of sample holders supplied
  - o Standard material calibration phantoms supplied
  - o Components for custom phantoms and objects supplied
- Physiological monitoring
  - o Ethernet and USB ports on sample bed for physiological monitoring
  - o Access port for oxygen and anaesthetic lines.
- Radiation shielding
  - o primary x-ray shield: 3.6 mm Pb
  - o secondary x-ray shield: 1.8 mm Pb shielded cabinet with frame

Spectral CT comparison



Anatomical imaging only

Limited material discrimination

Multiple material discrimination and quantification

MARS Spectral CT scanner Key Benefits

Delivers high spatial resolution material reconstruction and quantification.

By using the energy information captured by a Medipix 3 detector chip, MARS spectral CT delivers the next generation of CT imaging, with identification and quantification of both intrinsic and extrinsic materials, from low contrast materials such as lipid and water to high contrast materials including calcium, gadolinium and iodine.

Simultaneously differentiates and quantifies up to 6 different materials in a single scan.

The unique algorithm and processing of data allows the simultaneous detection and quantification of materials, with no additional scanning requirement. The benefits of simultaneous detection is the reduction of artefacts due to sample movement, as well as dose reduction and time savings.

Reduces metal artefacts.

The nature of spectral CT, and the use of photon counting and charge summing mode means that metal artefacts such as beam hardening can be removed during the reconstruction and material decomposition process.

Delivers improved tissue characterization.

Until now traditional CT offered poor differentiation of low contrast soft tissue, but, with material quantification, MARS spectral CT delivers assessment of the lipid/water compositionof soft tissue, with benefits to the research in the areas of fatty liver disease, atherosclerosis, obesity, and more.

Provides spectral molecular imaging with histology level information.

Using commercially available nanoparticle probes, MARS spectral CT provides histology level information about specific cell types within tissues, without the need for expensive radiotracers or low penetration fluorescent probes.

Provides new diagnostic x-ray information.

By using photon counting technology at multiple energy ranges, MARS generates more information than ever before, all stored in easily accessible DICOM format.

Offers access to both pre-reconstructed and post reconstructed data.

MARS systems come with a proprietary reconstruction algorithm, but users are also able to access all raw data and perform their own image processing and reconstruction.

Utilizes individualized scan protocols.

MARS spectral CT is designed for a wide range of applications; hence users are given the flexibility to design or adapt protocols to optimize their scans for their needs and specific applications. This includes the ability to change energy bins, voxel size, source to detector distance and more.

Enables low radiation dose due to ability to count single photons.

As all the information is contained within the energy of the photon and the distribution of photons, a high dose is not necessary to achieve a high-quality image. This has benefits for researchers planning to do longitudinal studies, repeatedly scanning the same subject.

Enables improving precision medicine.

MARS delivers accurate information about the location and density of specific targets, which offers the potential to improve the accuracy of dose calculation in treatments such as radiotherapy.

Advanced 3D visualisation and analysis of materials.

The MARS visualisation software allows users to view datasets in 2D and 3D with both qualitative, and quantitative assessment of materials. It incorporates a range of measurement tools, pre-defined colour look-up tables, the magic lens tool, and the HP Zvr - a state-of-the-art stereoscopic 3D virtual reality display with stylus input.

Dimensions, power requirements, and cooling:

Width = 1400 mm. Height = 1170mm from floor to top of lid. Depth = 750mm (can fit through a typical doorway). Weight: approximately 520kg. Power: 110 - 240 VAC, 10A Fan forced air cooling, in from underneath, out on left side. The scanner can be placed hard up against walls on the right and rear. Room temperature: 20°C - 25°C.

Physical design and scanner operation:

Access lid supported by gas struts and is on the centre-right of the cover. Ethernet, USB, mains power, keyed on/off, and provision for anaesthetic and sample cooling lines are on the left side. A monitor screen, a keyboard, and a mouse sit of the left-top cover, with their cables plugged at rear of cover. X-ray on light and emergency stop are on the right-top of cover. The cover can be opened for service after removal of two screws and is supported open by gas struts. The scanner is operated by using a Graphical User Interface (GUI) that controls the scanned area, the camera's energy thresholds and parameters such as the number of image frames per rotation.

Easily translatable to clinical human imaging.

The MARS scanner operates in the human energy range (30 -120 keV) and the applications demonstrated on MARS scanners are easily translated to human scale imaging.

Radiation safety.

The MARS small bore spectral scanner is intended for use in any laboratory. It is fully shielded for radiation protection and it does not require radiation monitoring. Radiation exposure from the scanner is less than 0.3mSv/yr, which is well below the radiation permissible limit (1mSv/yr) recommended by IAEA. No extra room shielding for radiation protection is required. It meets standards for cabinet x-ray equipment, for the use of x-ray security and inspection systems, although during commissioning the customer must ensure it meets any local regulations. Double circuit safety interlocks, on-light, and an emergency stop are provided.

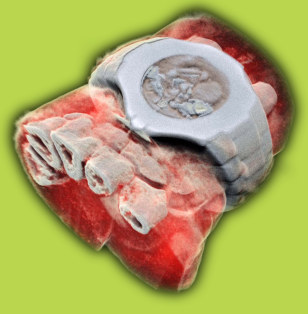
MARS orthopaedic imaging - launching soon!

MARS scanners offer high quality imaging, both high resolution and discrimination of materials.

Key features:

- o 80 µm voxel size
- o Metal artefact reduction
- o Seated position for patient
- o Small footprint for point of care use
- o 2D/3D hybrid image viewer
- o Length: 120cm, width: 75cm, height: 140cm. Height of arm entry: 100cm.
- o Material discrimination for soft tissue, lipid, water and metal
- o Simultaneous detection of multiple contrast agents



MARS customers & reference sites

"The MARS system is the only product on the market that enables my cutting-edge research to move forward as fast as possible. We are able to transition seamlessly between translation studies spanning from imaging phantoms to in vivo murine models."

Prof.
Ryan Roeder
University of Notre Dame

"My lab is blessed to have the latest MARS photon-counting micro-CT scanner. This spectral (multi-energy) micro-CT scanner will be used for preclinical research and translation to clinical applications such as targeted nanoparticle / drug delivery and quantitative molecular imaging."

Chair Prof.
Ge Wang
Rensselaer Polytechnic Institute

"The MARS scanner in UOC has provided an opportunity to Christchurch researchers to be at the forefront of developing new clinical applications for photon counting CT modality. By using this novel system, my research group has produced remarkable results on many aspects of the medical applications of spectral CT imaging such as molecular imaging of tumours, drug delivery, atherosclerosis and bone quality"

Lecturer
Dr Aamir Younis Raja (PhD)
University of Otago, Christchurch

"The MARS scanner gives us the ability to rapidly and non-destructively characterise atherosclerotic plaques at high resolutions. Without this technology we would be unable to compare the biochemistry of the plaques and understand the effect of calcification on cell behavior."

Associate Prof.
Steven Gieseg
University of Canterbury, New Zealand

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