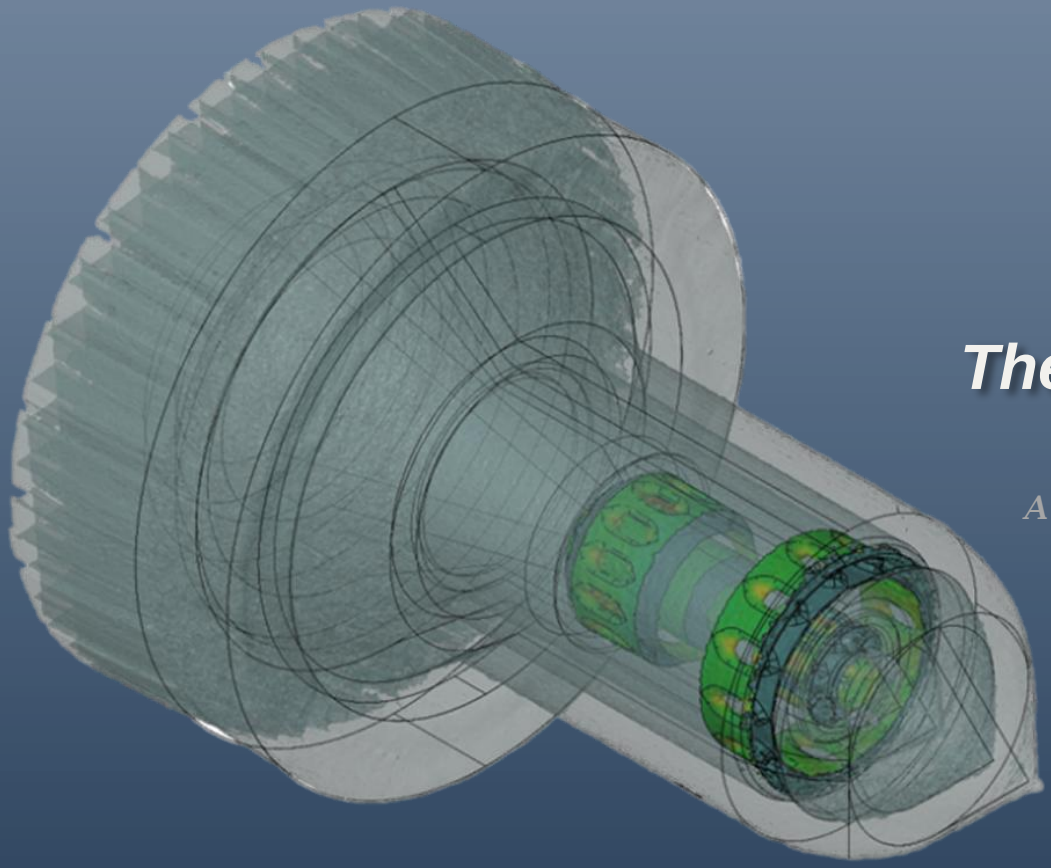


UNIVERSITY OF Southampton

The μ-VIS micro-focus CT Centre

A shared multi-disciplinary centre for high resolution X-ray computed tomography

X-ray CT of geometrically complex metallic parts

Dr. M.N. Mavrogordato

μ-VIS CT Imaging Centre
University of Southampton,
United Kingdom.

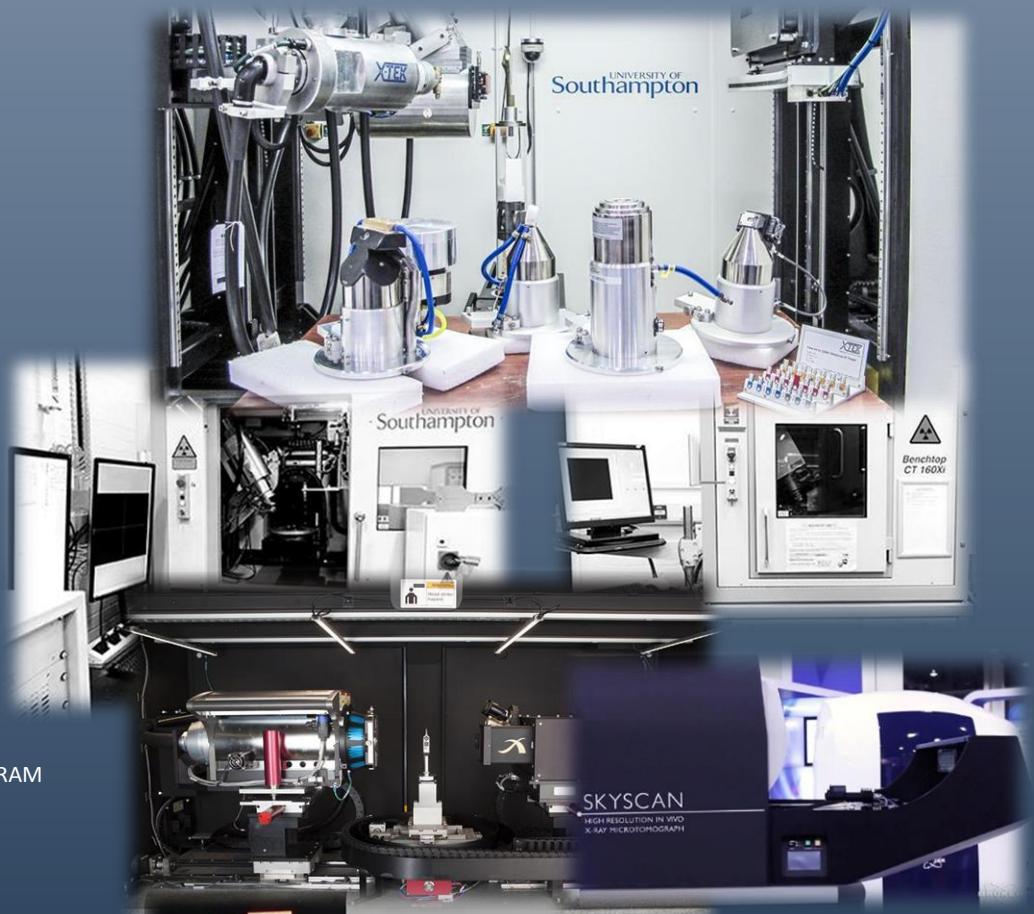
mnm100@soton.ac.uk
muvis@soton.ac.uk

www.muvis2.org

μ–VIS:

- **£2.2M startup investment by EPSRC (£1.9M) & UoS (0.3M)**
- **7 micro focus X-CT systems:**
  - Benchtop 160 (Nikon Metrology, UK).
  - XT H225 L with custom robotic sample exchanger (Nikon Metrology, UK).
  - Custom built dual source (450/225kV) walk in room (Nikon Metrology, UK).
  - Zeiss Xradia versa 510 (Carl Zeiss X-ray Microscopy Inc., USA)
  - SkyScan 1176 in-vivo CT scanner
  - Nikon Med-X (alpha)
  - MetalJet dual beam system (in development)

- **Dedicated image analysis suite**
  - 13 high-specification, dual-socket workstations with between 96 - 512 GiB RAM each
  - Dedicated fast 10Gbit data transfer network.
  - Dedicated, high speed storage with over 350 TB raw capacity
  - Leading commercial and open-source software packages available



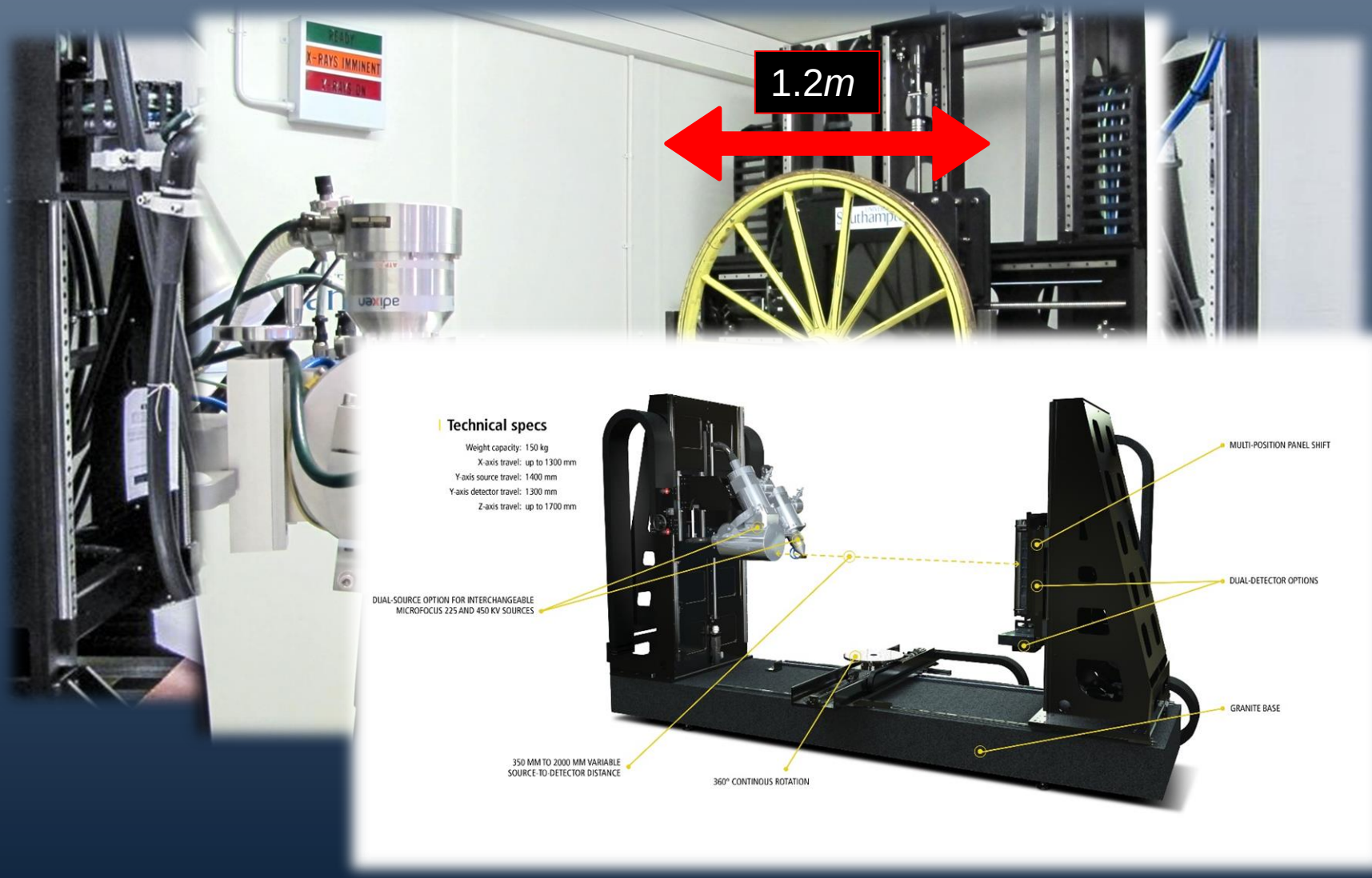
Avizo

IDL

simpleware
converting 3D images into numerical models

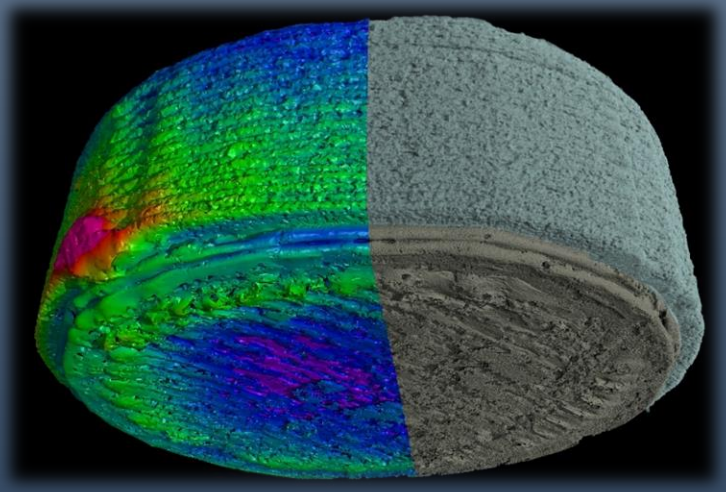
VGStudio MAX

μ–VIS:


READY
X-RAYS IMMINENT
1.2m
Technical specs
Weight capacity: 150 kg
X-axis travel: up to 1300 mm
Y-axis source travel: 1400 mm
Y-axis detector travel: 1300 mm
Z-axis travel: up to 1700 mm
DUAL-SOURCE OPTION FOR INTERCHANGEABLE MICROFOCUS 225 AND 450 KV SOURCES
350 MM TO 2000 MM VARIABLE SOURCE-TO-DETECTOR DISTANCE
360° CONTINOUS ROTATION
MULTI-POSITION PANEL SHIFT
DUAL-DETECTOR OPTIONS
GRANITE BASE

AM components & considerations – Wish list for X-CT inspection

- Be able to provide non-destructive means for:
  - *Actual-nominal comparisons*
  - *Defect detection and quantification*
  - *Porosity analysis/distribution*
  - *Internal surface roughness characterisation*
  - *Image based modelling*
  - *Support for other inspection techniques*



3D-printed pharmaceutical with actual-nominal comparison via X-CT: EJPB (under review)

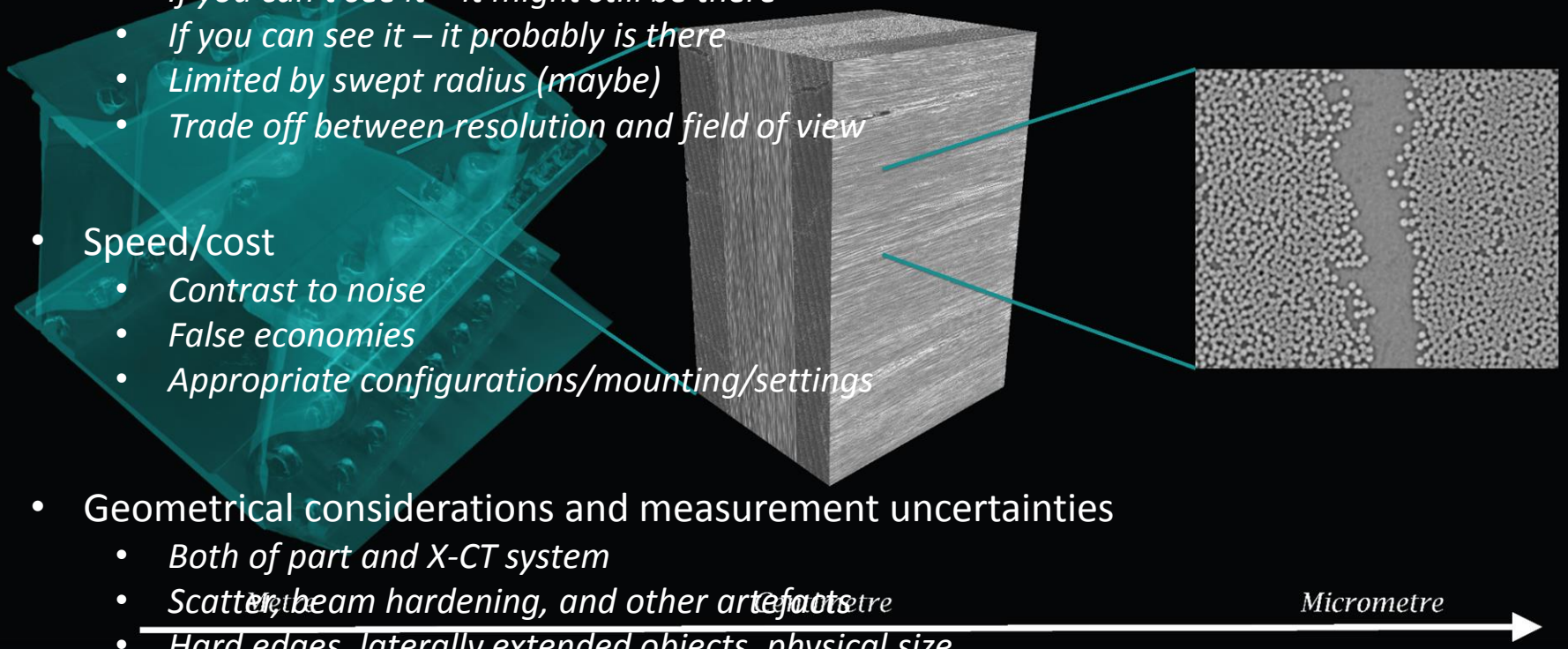
- Able to cope with a wide range of:
  - *Material types*
  - *Geometries*
  - *Sizes*
  - *Densities*

- Whilst giving:
  - *High resolution*
  - *High accuracy*

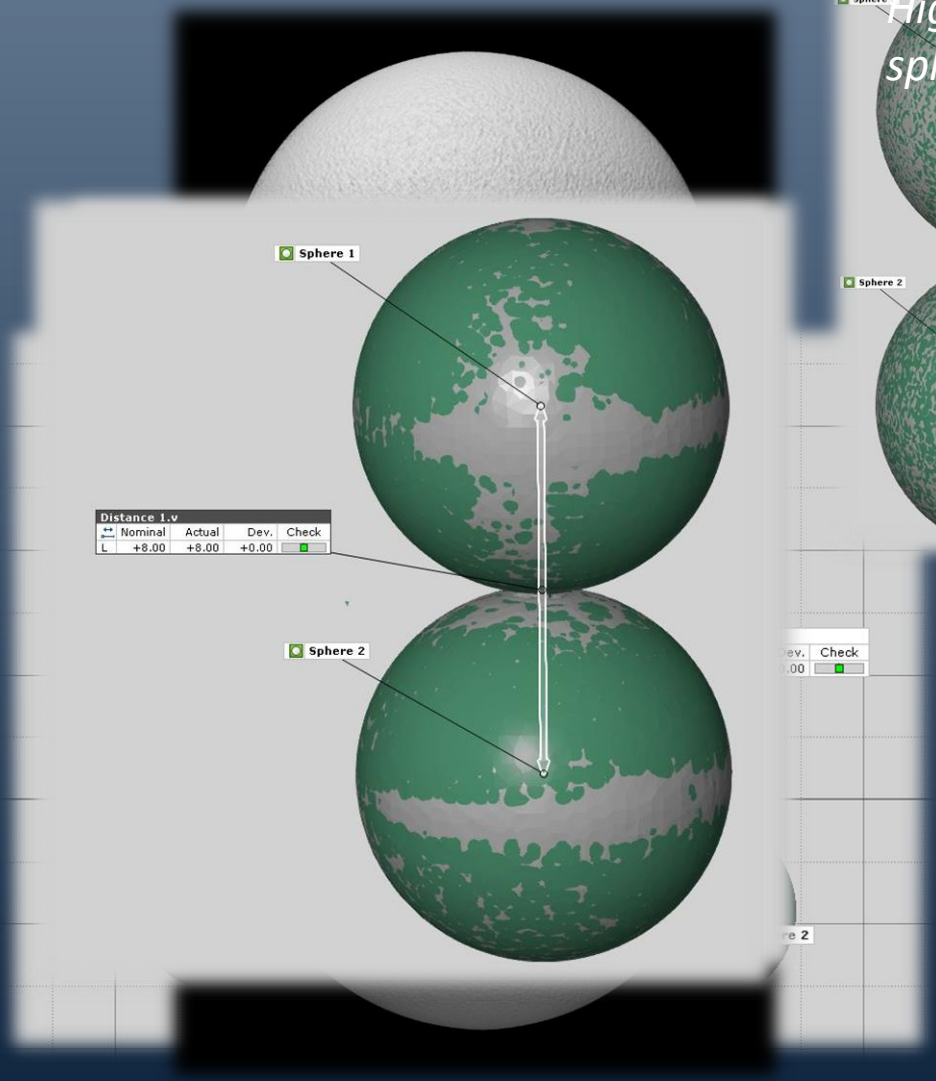
- And being:
  - *Low cost*
  - *Fast*
  - *Traceable*

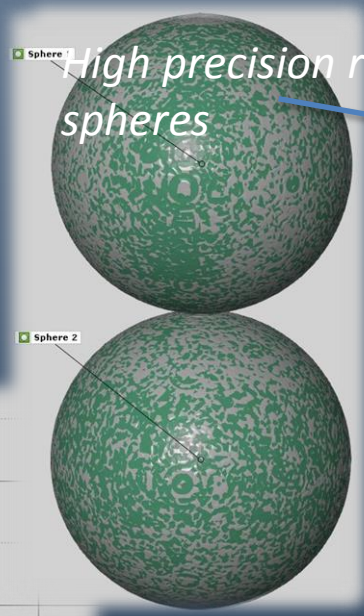
AM components & considerations – X-CT reality

- Resolutions requirements
  - *The closer you look, the more you see (if you can)*
  - *If you can't see it – it might still be there*
  - *If you can see it – it probably is there*
  - *Limited by swept radius (maybe)*
  - *Trade off between resolution and field of view*
- Speed/cost
  - *Contrast to noise*
  - *False economies*
  - *Appropriate configurations/mounting/settings*
- Geometrical considerations and measurement uncertainties
  - *Both of part and X-CT system*
  - *Scatter, beam hardening, and other artefacts*
  - *Hard edges, laterally extended objects, physical size*

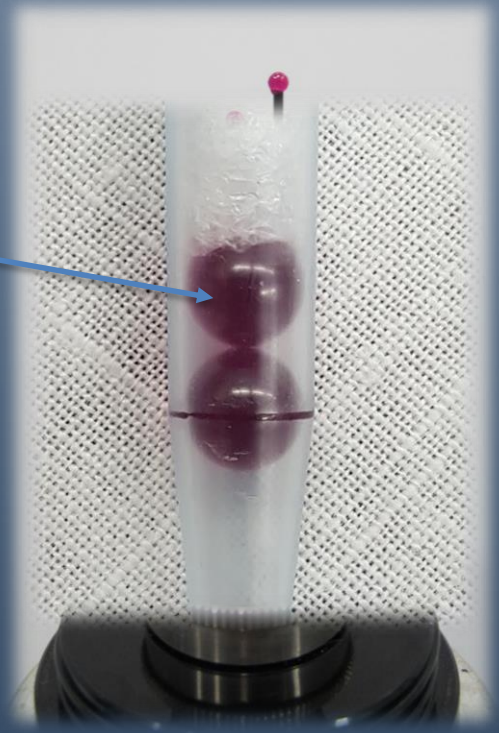


Using CT for geometrical measurement – Secure foundations





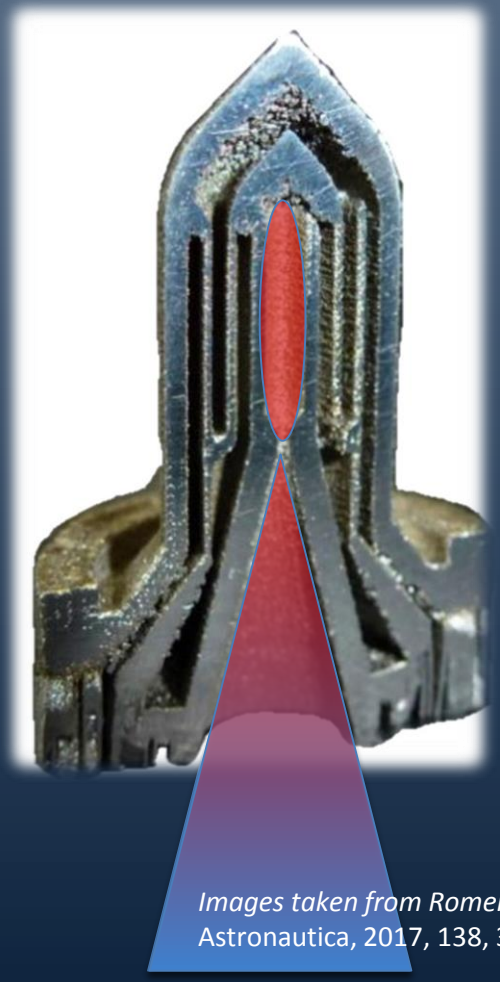
High precision ruby spheres

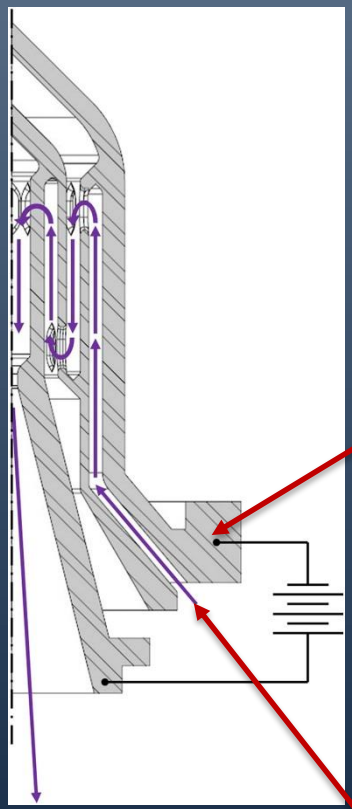


Beam alignment and focus
Source height
Detector tilt
X-axis backoff
Source – Mag zero
Source – Detector distance
"Settings": kV, power, projections, exposure, filtration etc.

Vanilla (AM) parts: Small, cylindrical, low(ish) density (Stainless Steel) – The Resistojet

Photograph courtesy of Matthew Robinson (UoS PhD student working on the project)



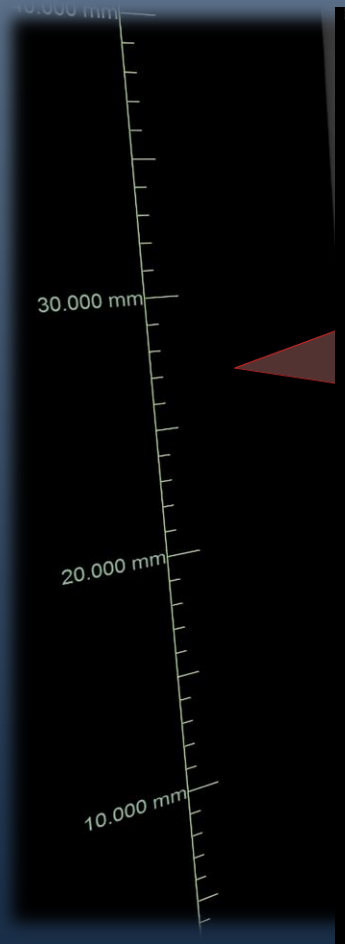


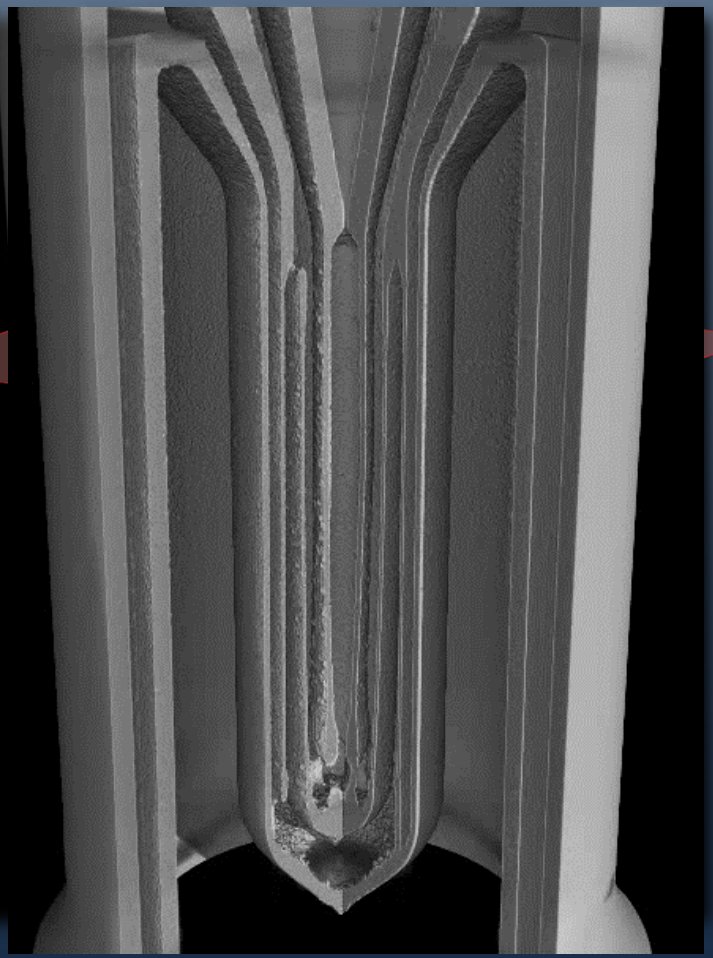
Electrically heated element

Propellant fluid (e.g. Nitrous oxide)

Images taken from Romei et al. Acta Astronautica, 2017, 138, 356-368

Vanilla (AM) parts: Small, cylindrical, low(ish) density (Stainless Steel)





System: Custom dual source 450/225 walk in room

Basic settings:

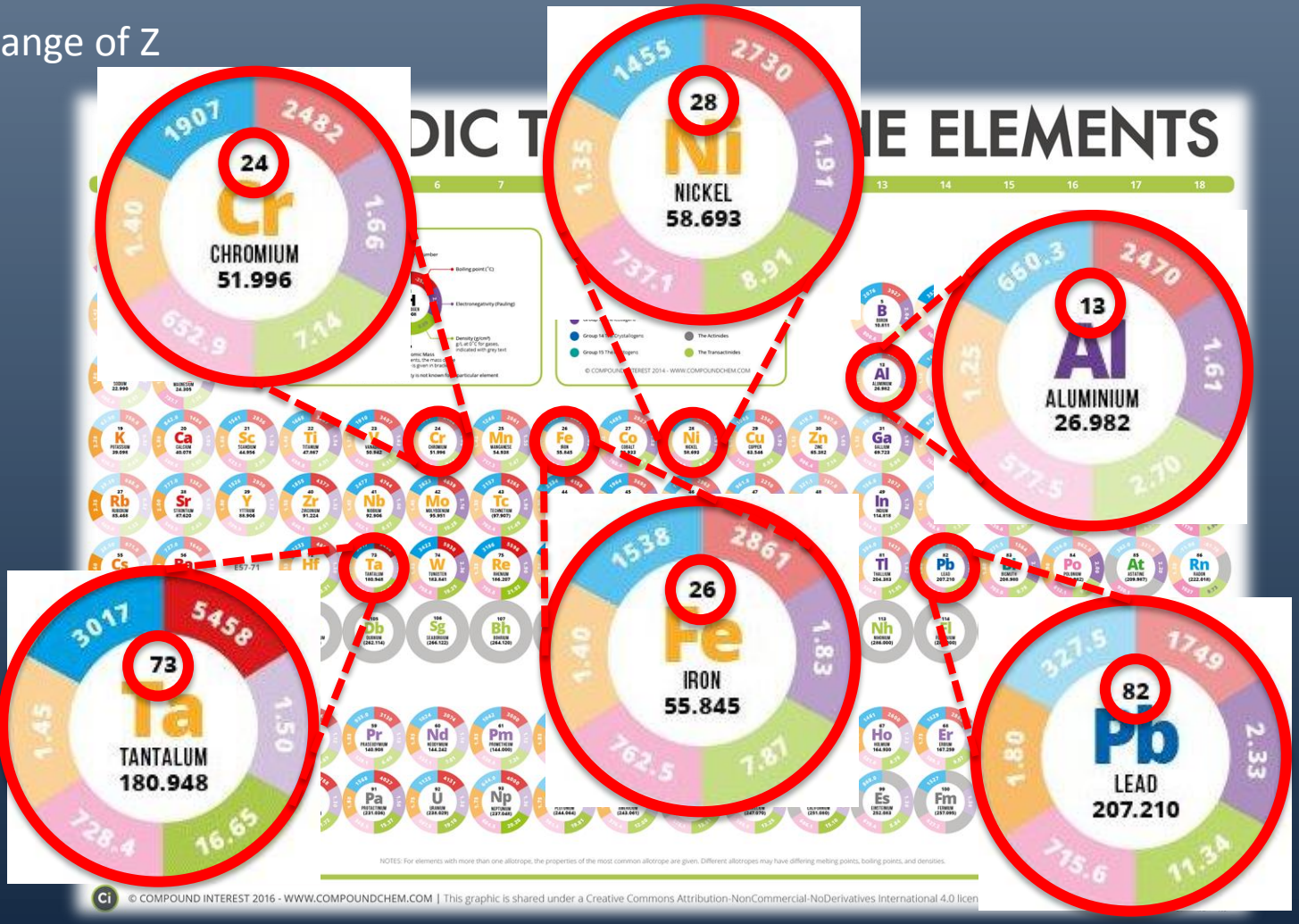
- *200kV*
- *50W*
- *1hr scan time*
- *25µm voxel size*

Could have used HMX, but also used:

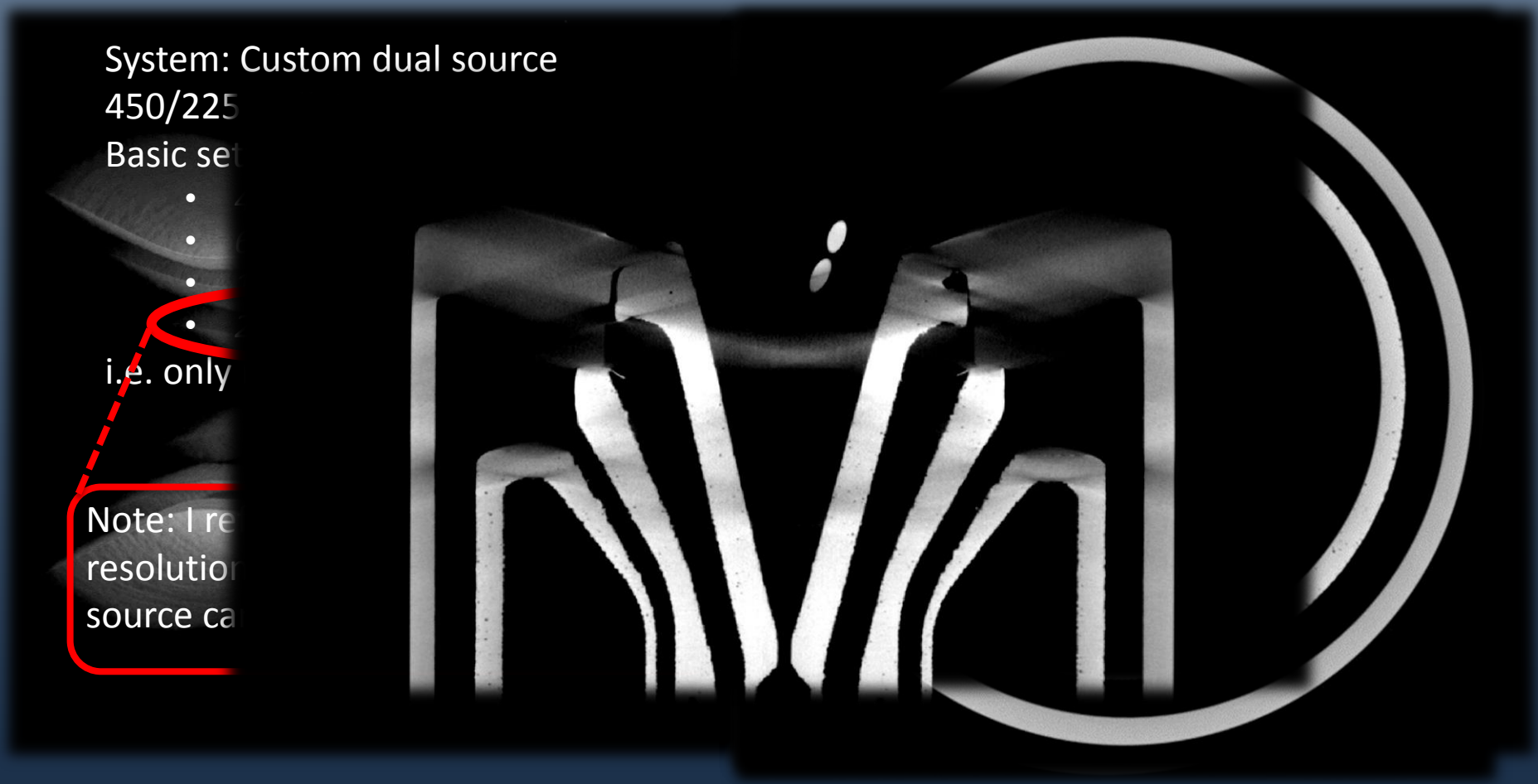
- *source-detector distance ~650mm*
- *rotating anode target*
- *CsI scintillator*

AM components & considerations

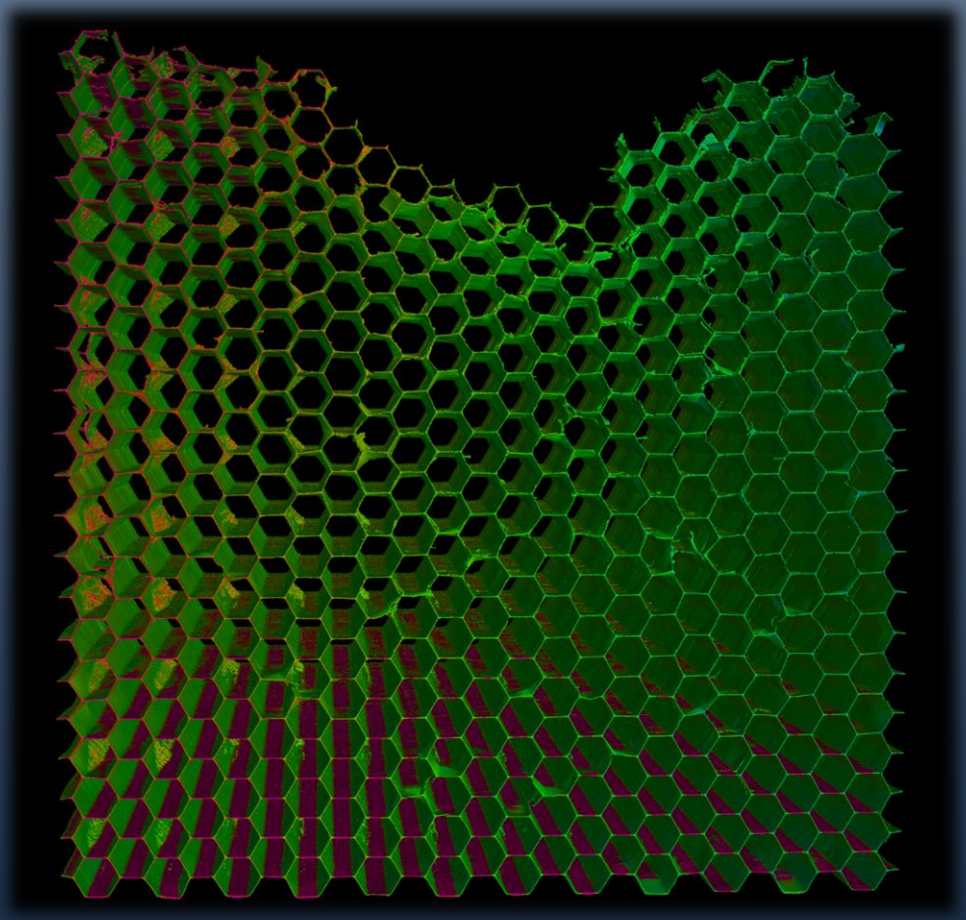
- Range of Z

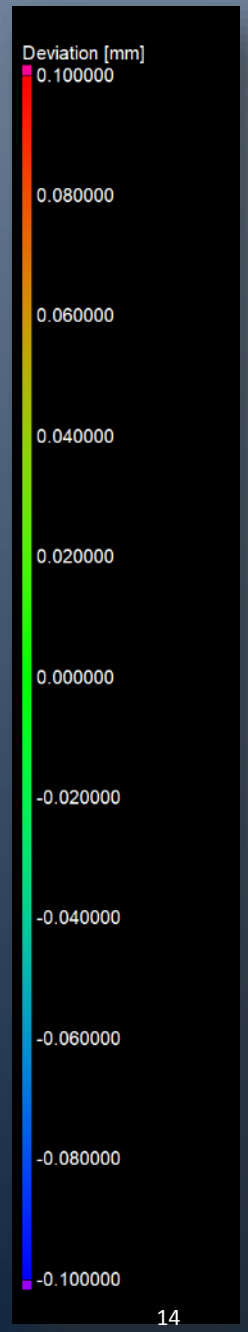


AM parts: Small, cylindrical, high density (Tantalum)



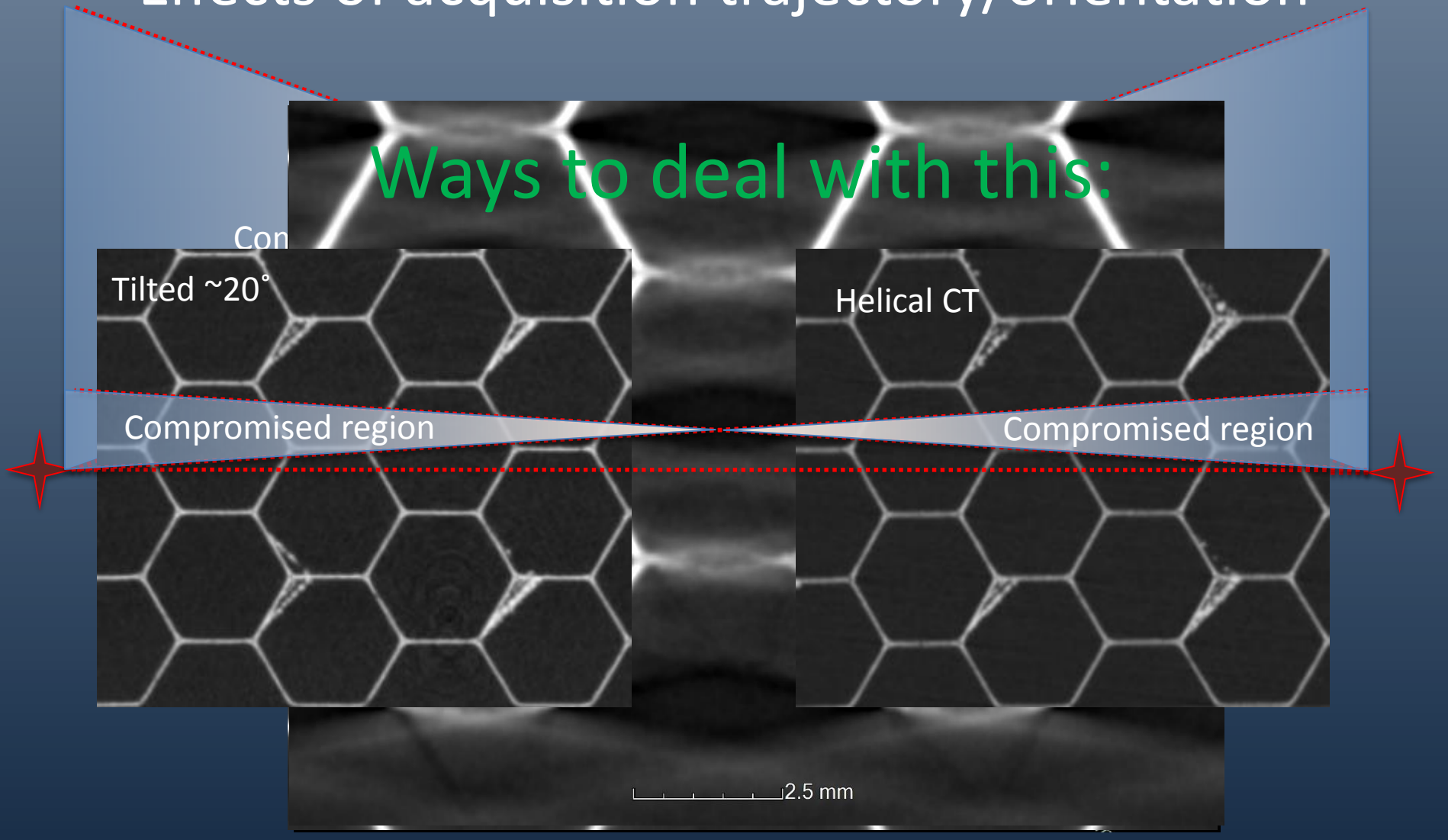
Actual-Nominal comparisons





Honeycomb specimens scanned as part of the Redshift H2020 programme
http://redshift-h2020.eu/

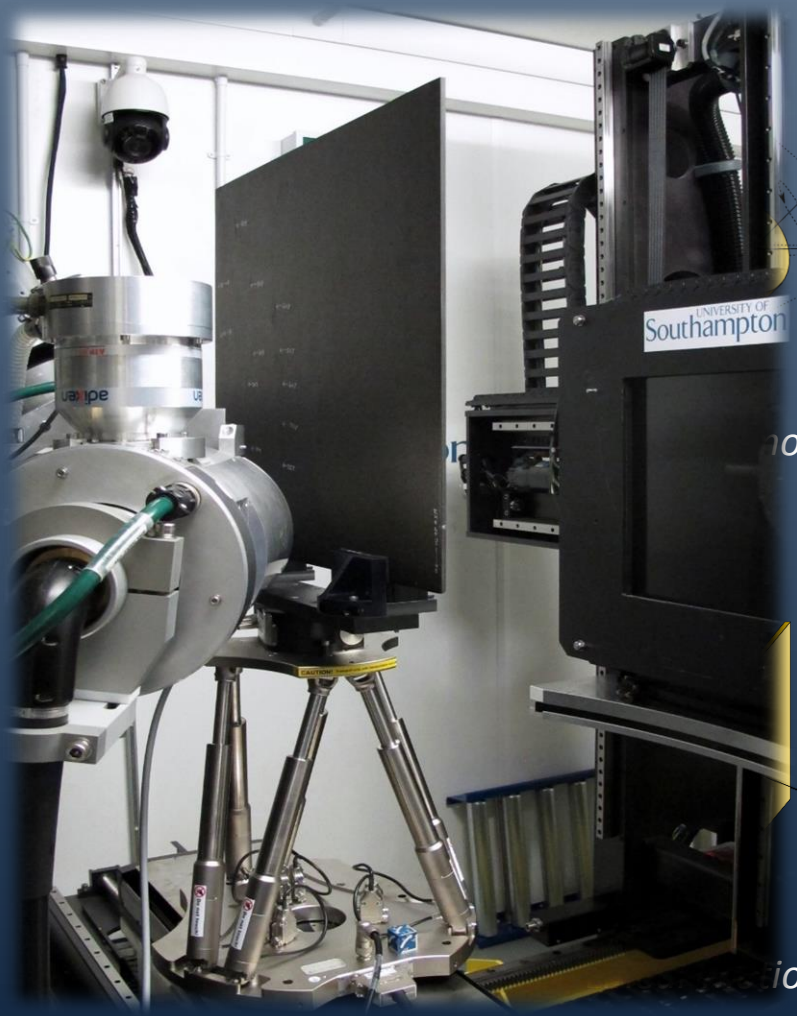
Effects of acquisition trajectory/orientation



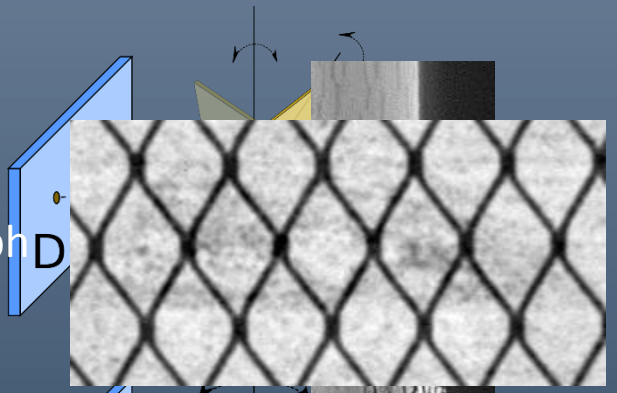
Honeycomb specimens scanned as part of the Redshift H2020 programme
http://redshift-h2020.eu/

Helical scan courtesy of Oliver Larkin (Nikon Metrology UK)

Non-standard trajectory acquisition



Radiograph

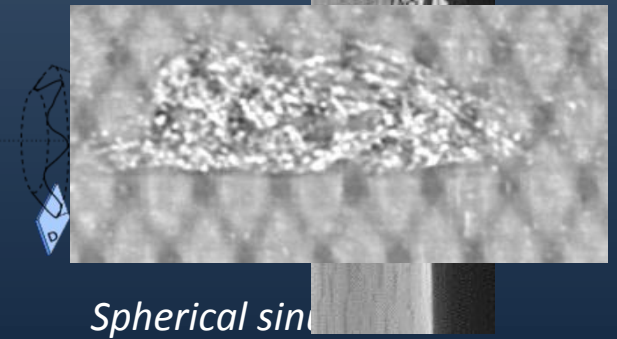


More on this in talk by George Mann (Weds 1545hrs)

Backprojection

(limited-ang

Iterative recon

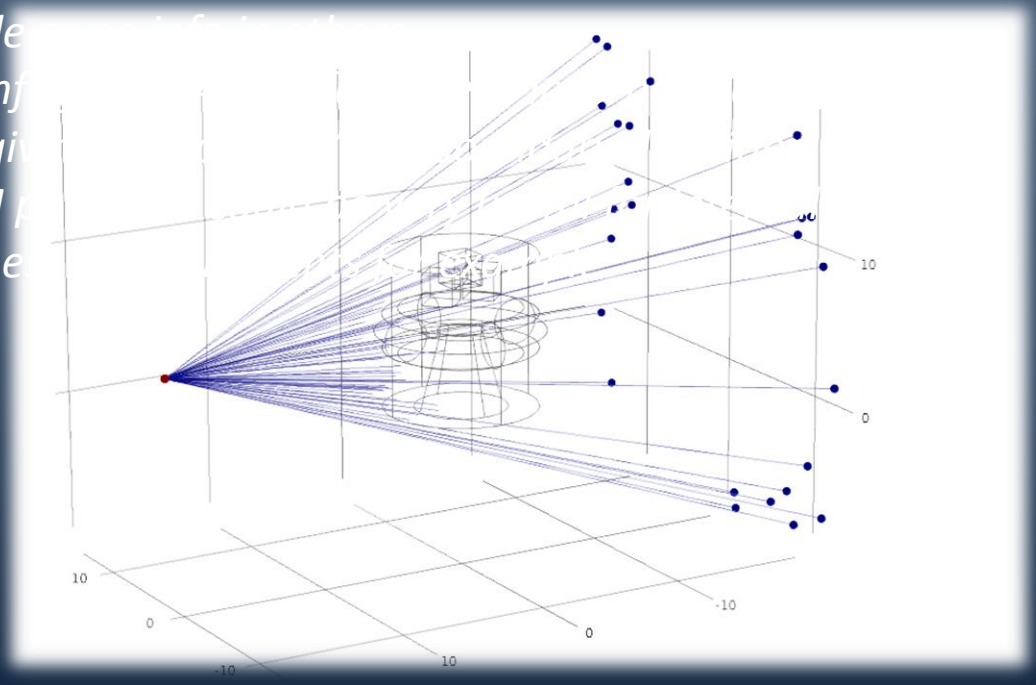


Spherical sin

O'brien et al, Journal of X-Ray Science and Technology, 2016, 24(5), 691-707

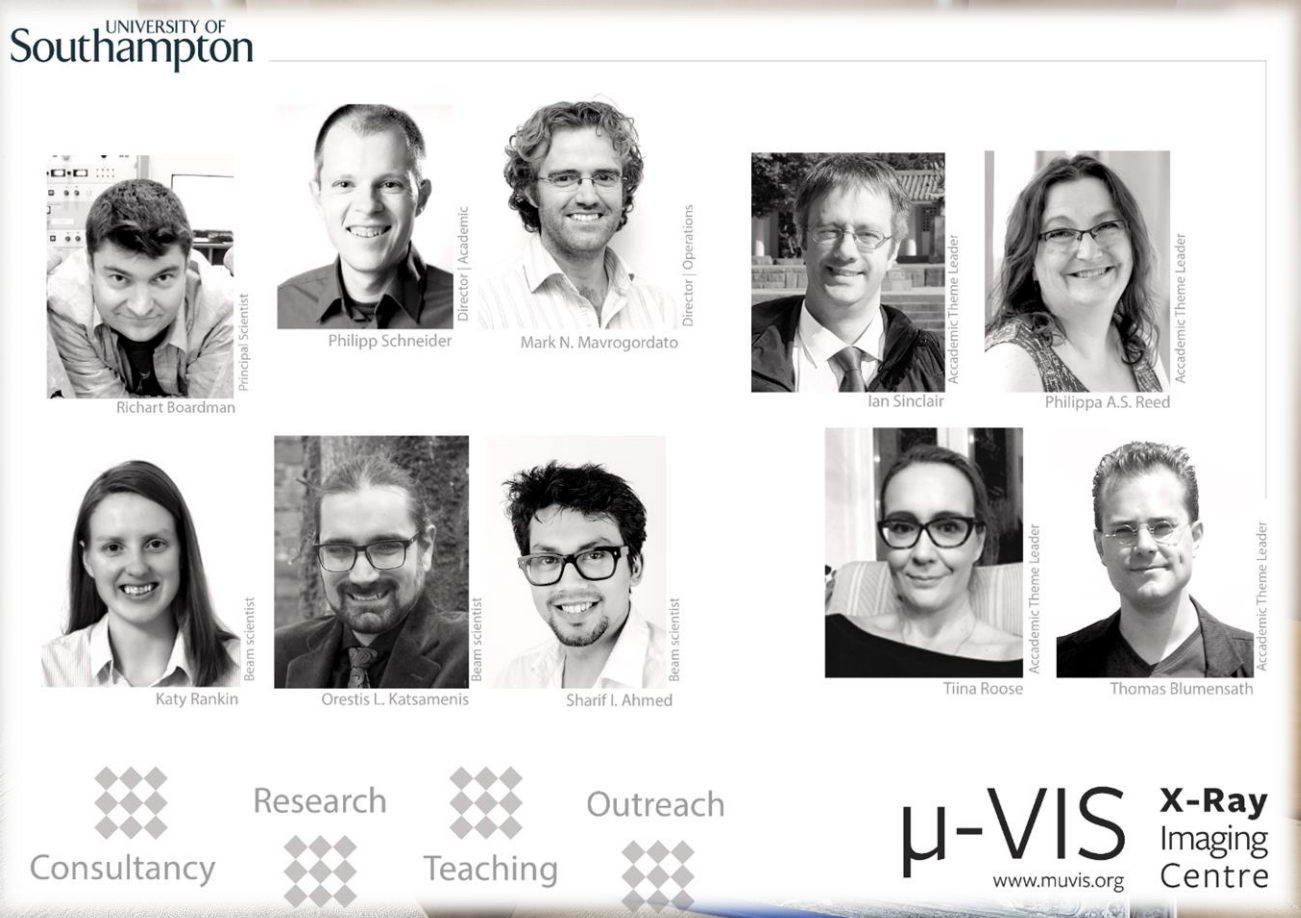
Model constrained reconstruction methods

- 3 year EPSRC funded project - *start date 01/01/2018*
- Use CAD data to constrain x-ray tomographic reconstruction:
  - *Reduced angle scans give a lot of info in some directions, but little*
  - *Priori inf*
    recon gi
  - *For AM p*
    roughne



Despite all the tools, everything still depends on…

The Operators



Acknowledgements:

- Orestis Katsamenis *(µ-VIS, University of Southampton) – AM Pharmaceutical Actual/nominal*
- Angelo Grubisic, Federico Romei, Matthew Robinson, Chris Ogunlesi, Sharif Ahmed *(University of Southampton) – Resistojets*
- Scott Walker *– Redshift honeycomb structures*
- Oliver Larkin, Ian Haig *(Nikon Metrology, UK) – provision of helical scans using metrology system, plus actual-actual comparison*
- Thomas Blumensath, Neil O'Brien, Charles Wood *– ATI funded project CAN*
- Thomas Bluemensath, Richard Boardman, Ander Biguri, Hussein Towsyfyan *– CAD informed reconstruction mathods*
- The whole µ-VIS team

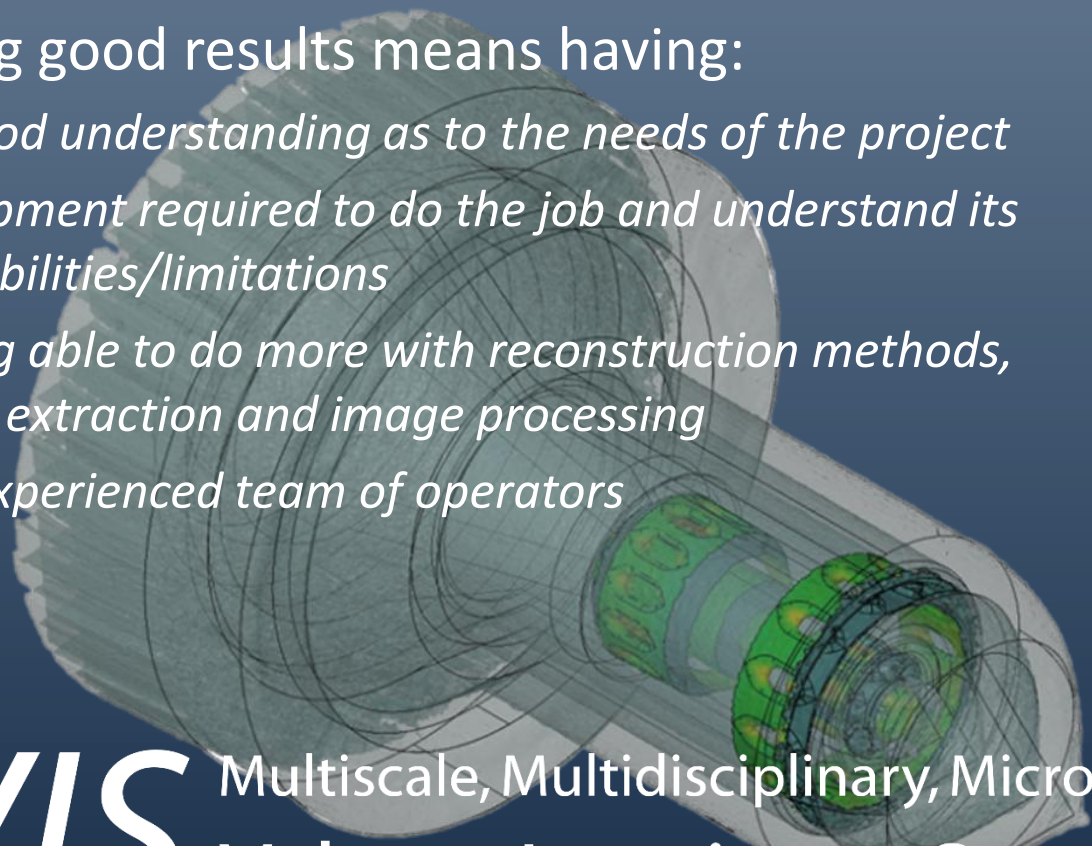
µ-VIS

www.southampton.ac.uk/muvis

Multiscale, Multidisciplinary, Microtomographic Volume Imaging at Southampton

Take home message:

- Getting good results means having:
  - *A good understanding as to the needs of the project*
  - *Equipment required to do the job and understand its capabilities/limitations*
  - *Being able to do more with reconstruction methods, data extraction and image processing*
  - *An experienced team of operators*



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Multiscale, Multidisciplinary, Microtomographic Volume Imaging at Southampton

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