e2v

COMSOL Multiphysics enhances design process at e2v technologies

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e2v

COMSOL CONFERENCE 2009

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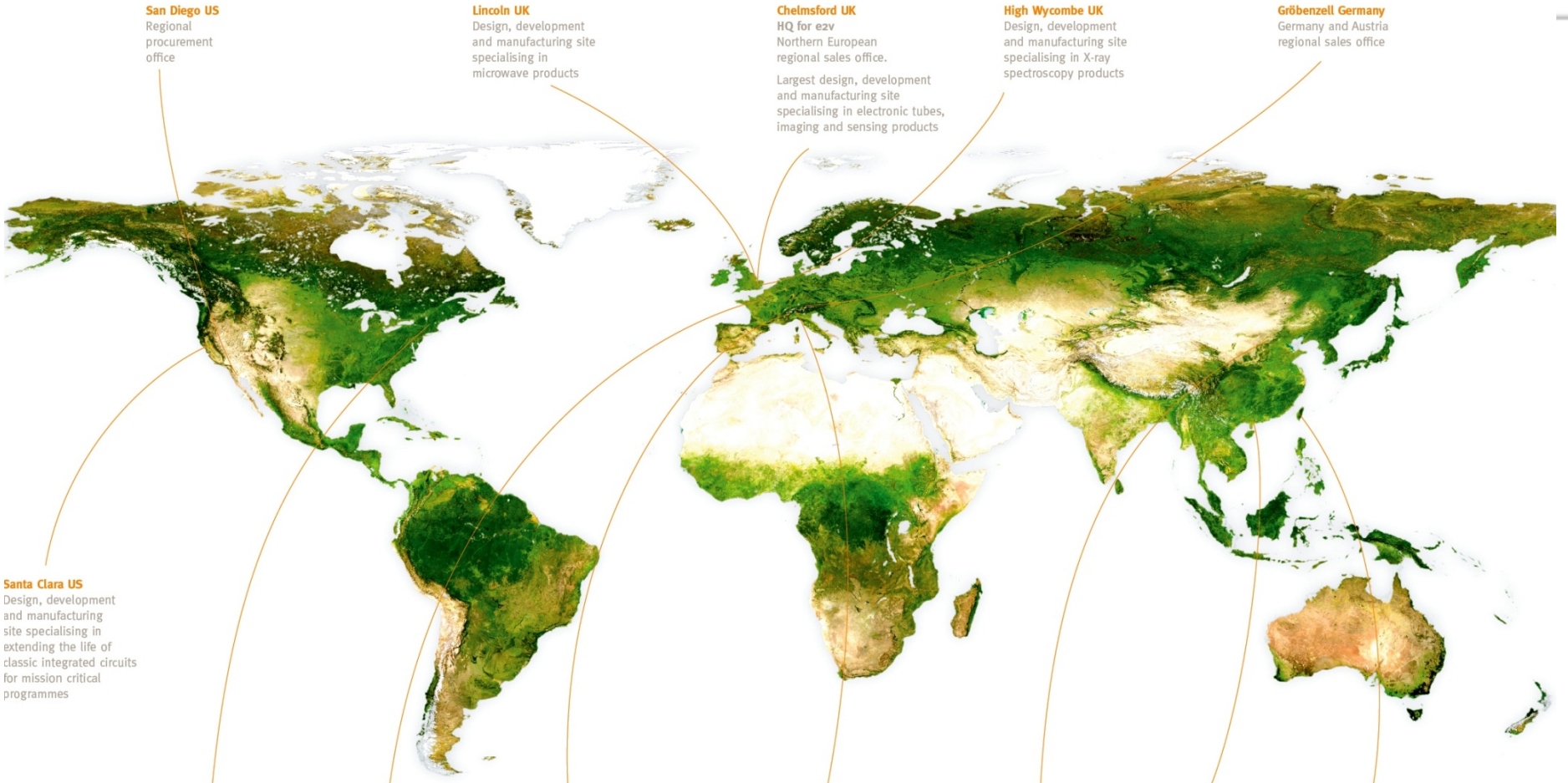
Content

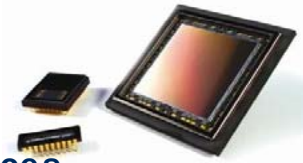
- Short introduction to e2v
- Some of the products and processes
- Modelling at e2v
- New directions to expanding our market
- Justifying a new modelling tool
- Some examples

International business - 1800 employees in 13 locations

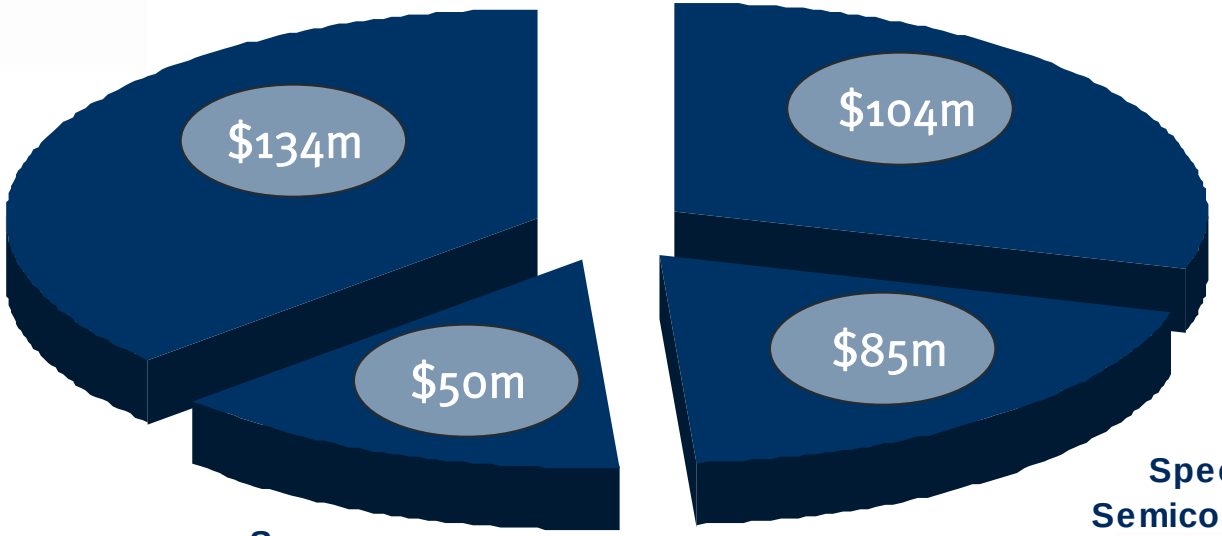


e2v product group

Electron Devices & Sub-Systems

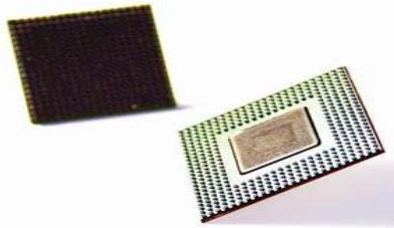


Imaging Devices



Sensors

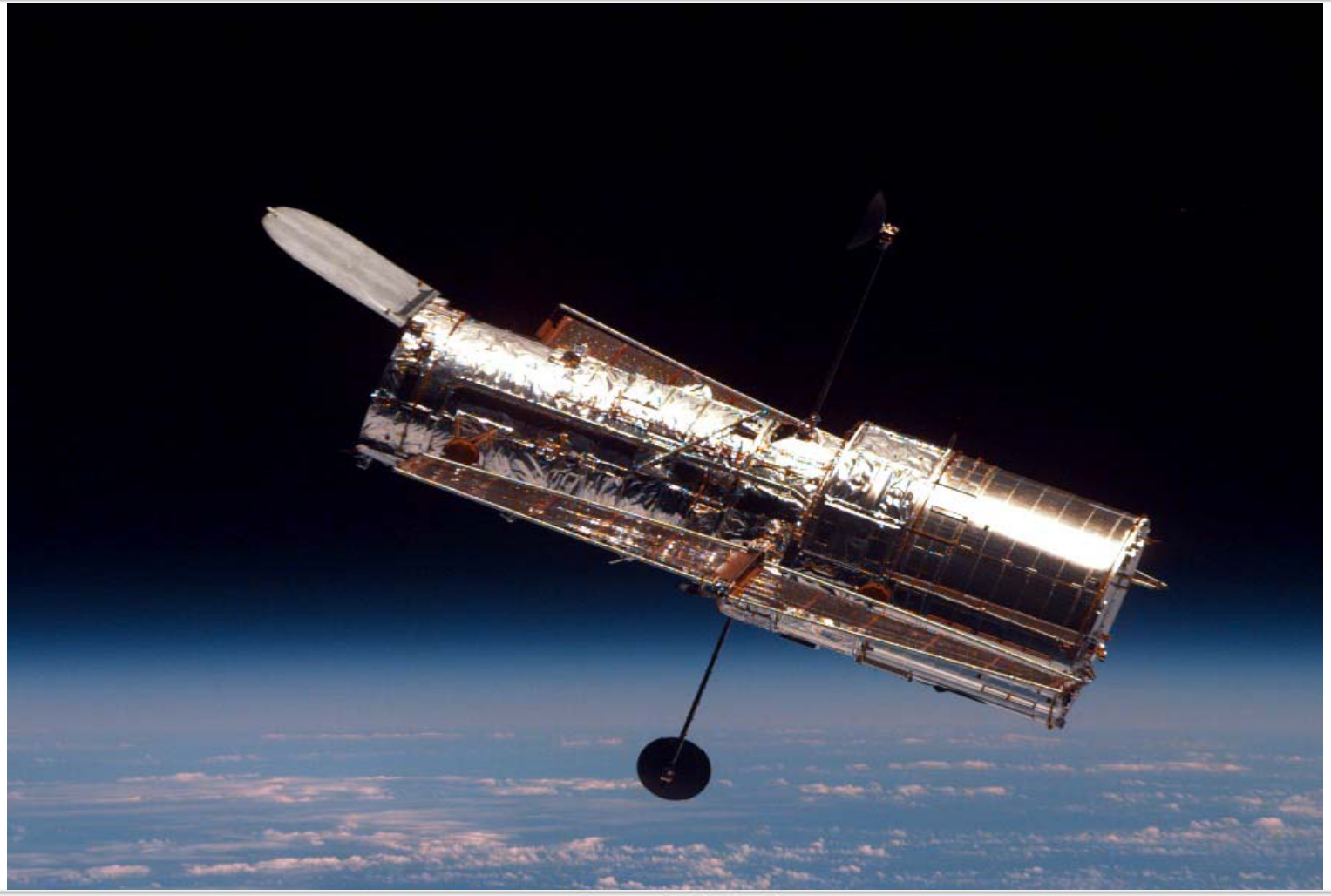
Specialist Semiconductors



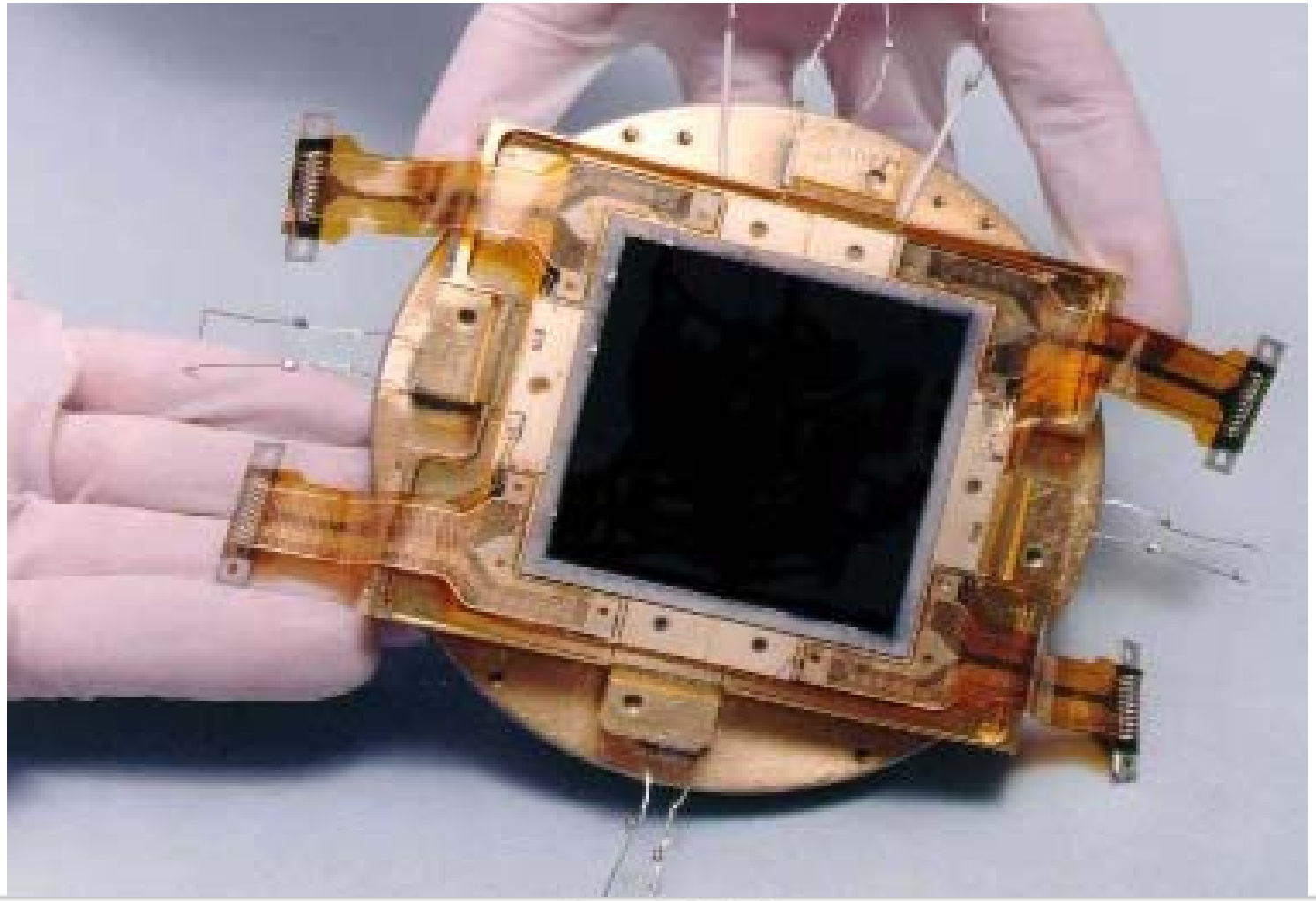
Based on exchange rate of 1.6$/£

Our major customers and partners

e2v in the news:
Hubble Space Telescope



Hubble Space Telescope uses e2v WF3 CCD camera sensor



First image from Hubble using WF3 CCD

Some applications in the EDS group

- Major supplier of magnetrons to linear accelerator (LINAC) manufacturers

- Used in Cargo inspection
- Cancer therapy (Radiotherapy)

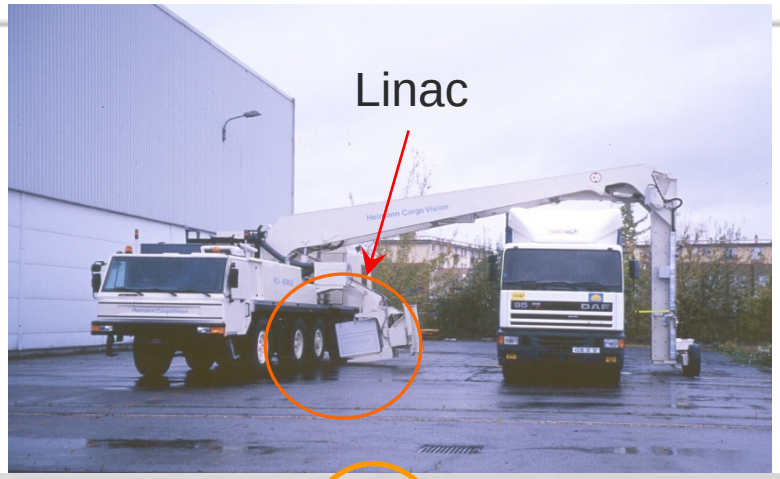
- Thyratrons (high voltage and high current switches for science)
- Travelling wave tubes (broadband amplifying tubes for broadcast up links)
- Gridded vacuum tubes (RF and induction heating, plasma generation and laser pumping)

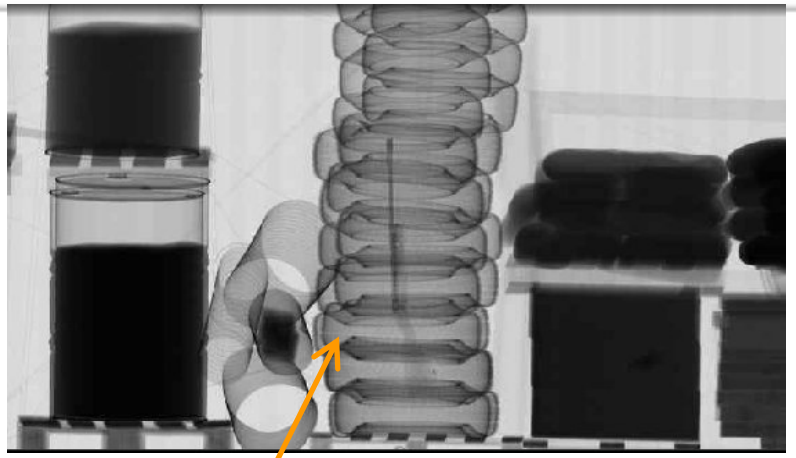
- Most are vacuum electron tubes

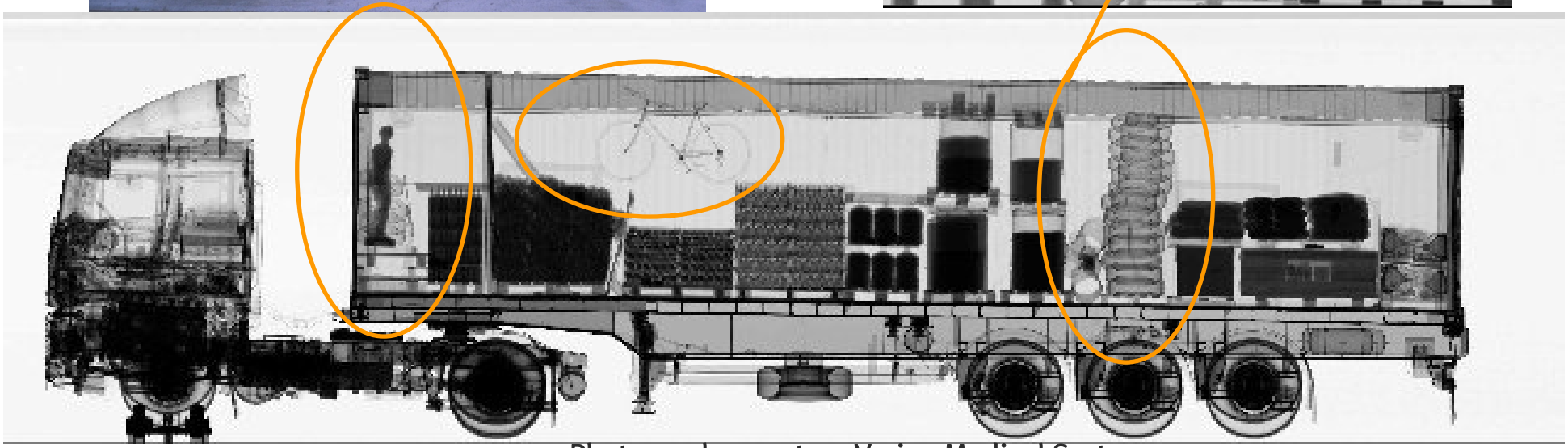
Real time high energy x-ray inspection

- Linear accelerator (Linac) uses high power microwaves generated by e2v magnetron
- To produce high energy electrons (5 to 9 MeV)
- Electrons impinge on target (tungsten) producing x-rays
- Real time imaging system used to display x-ray image of contents of cargo container and truck
- Such system in place worldwide

Cargo inspection

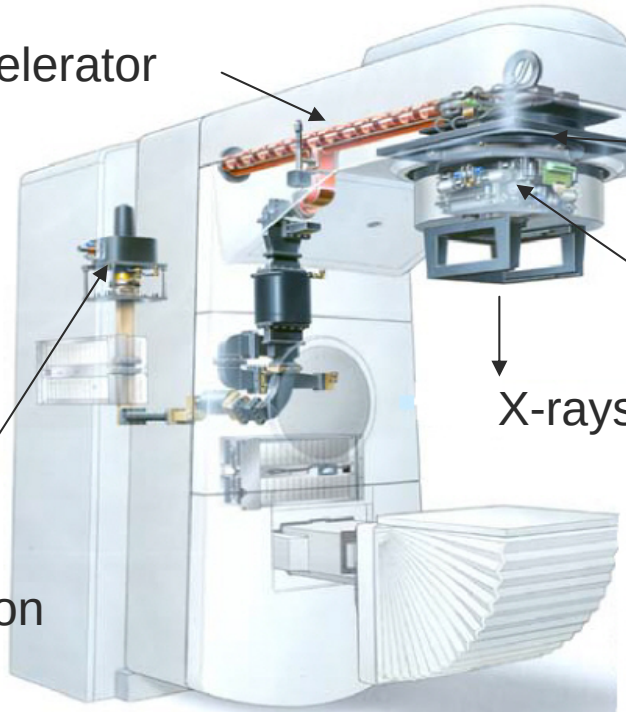






Photographs courtesy Varian Medical Systems

Radiotherapy LINAC machine schematic

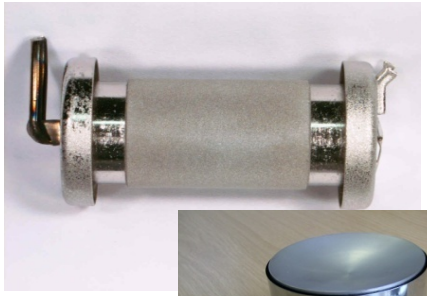


The magnetron has a precision tuner to allow frequency to be adjusted to match that of linac

High speed electromagnetic version is patented innovation

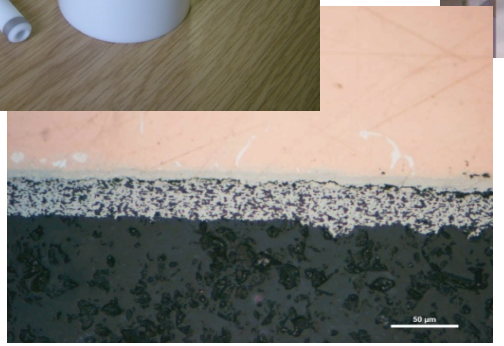
Key step in enabling IMRT

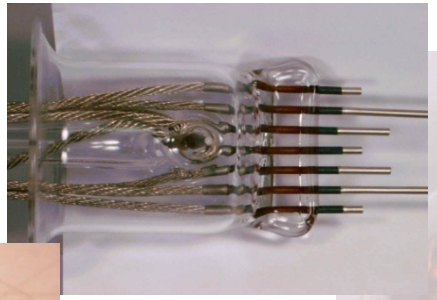
Some key component capabilities



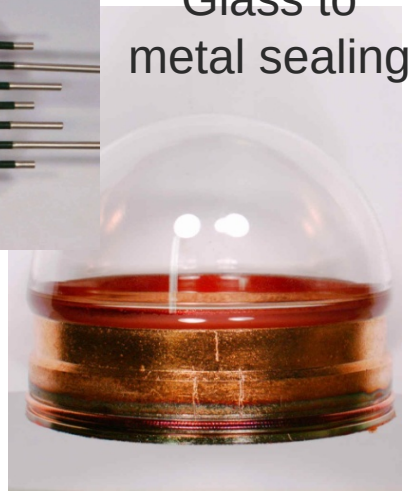
Cathodes

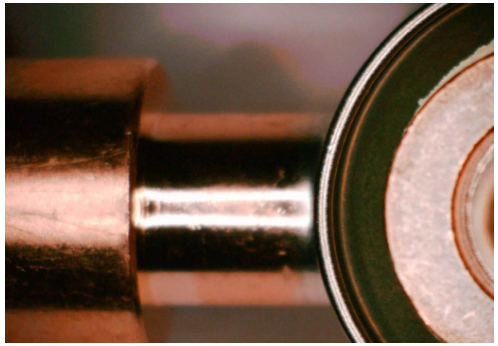
Metallising & brazing



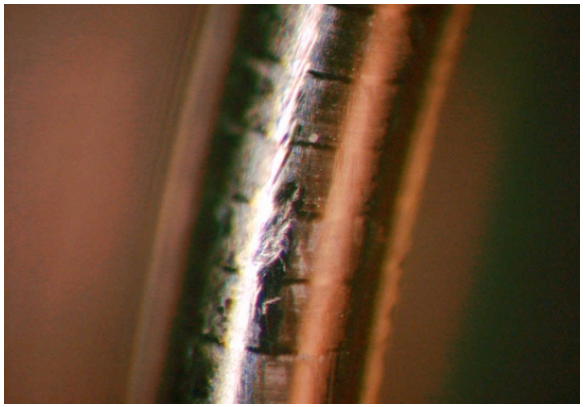


Glass to metal sealing

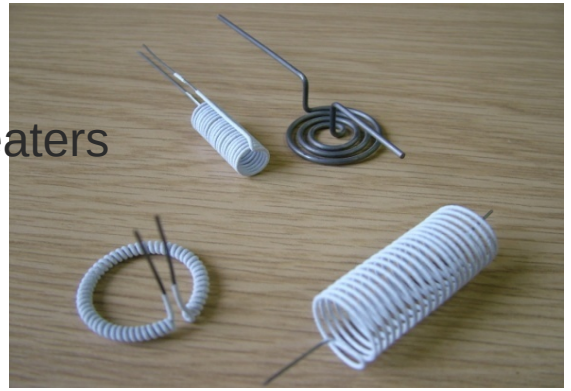




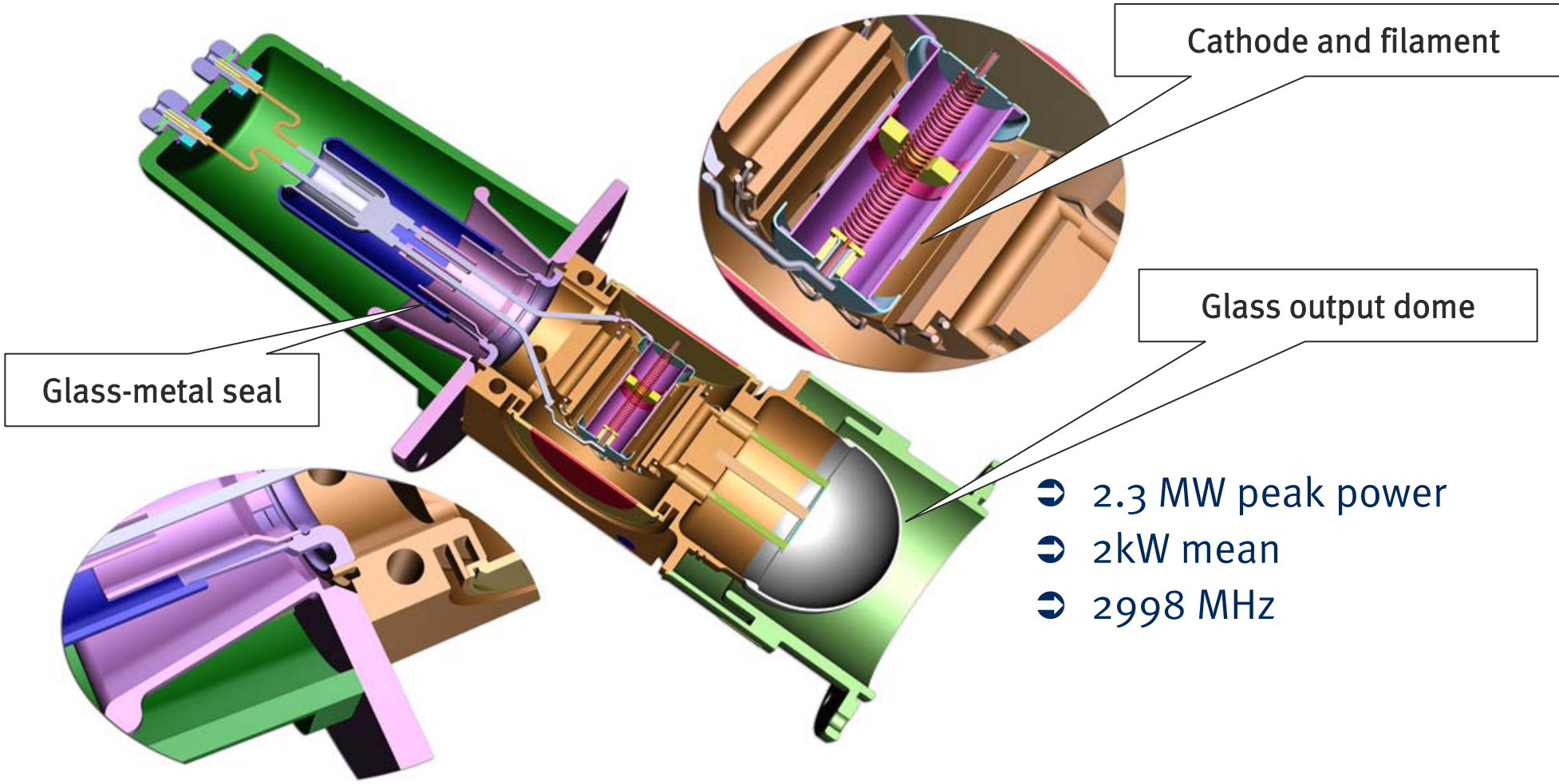
Welding



Heaters



Typical LINAC magnetron



- 2.3 MW peak power
- 2kW mean
- 2998 MHz

Some Process Capabilities

- Traditional chemistry laboratory for analysis
- Electron microscopy
- Material testing laboratory

- Electroplating
- Various welding: automated
- Furnaces: hydrogen and vacuum

Modelling Software at e2v

- CFD (Fluent, CFX, Gambit, and ICEM)
  - Fluid Mechanics and thermal analysis (solids / liquids / gasses)
- ANSYS
  - Structural and thermal analysis
- Mafia
  - Particle in Cell analysis
- CST Microwave Studio
  - RF systems analysis
- COMSOL
  - Full multi-physics analysis (RF, CFD, Thermal, Structural, and Chemical)
- Materialise (Mimics and 3-Matic)
  - Meshing of CT scan data

How do you justify another modelling tool?

- Modelling software licensing costs >€140k per year

- In the last couple of years we have started to explore application-driven products to grow our business
- This means not just supplying the RF or microwave tube but using our expertise to assist in the whole product design

- Assist in complete product/process design
- Much interest in using RF and microwaves in many differing processes.
  - Mining industry
  - Oil industry
  - Food industry

- Any new software has to demonstrate benefit or added value quickly

How does COMSOL Multiphysics help?
The real world is Multiphysics

The application of RF or microwaves to any material results in

- Heat
  - Temperature related material properties
    - Change in RF or microwave properties
      - Dielectric constant and dielectric loss
        - Risk of thermal runaway
  - Temperature rise
    - Thermal conduction
      - Thermal expansion
        - Mechanical stresses and strains
        - Risk of fracture/deformation
  - These are not normally one-way interactions
  - It's a Coupled Multiphysics world!

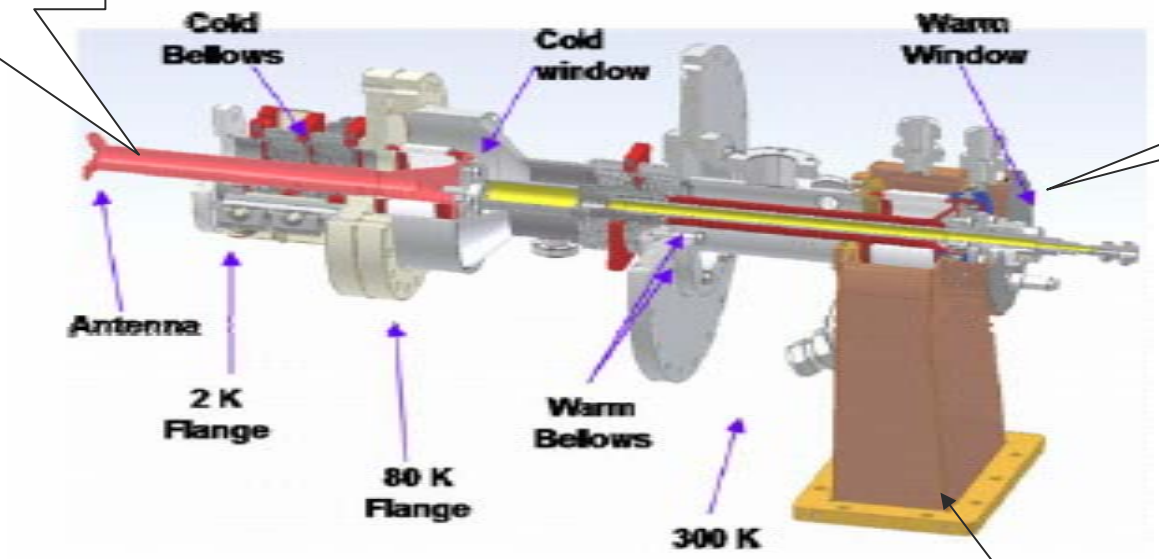
COMSOL Multiphysics in action at e2v

Superconducting L Band 50kW RF Coupler

Cryogenically cooled
<2 Kelvin

Normal Ambient Temperature

LINAC



Input power Waveguide
50 kW 1.3GHz

Superconducting RF Coupler:
The problem:

- Complex assembly with large temperature difference
- Significant RF losses in copper plating and ceramic volumes

- Solution

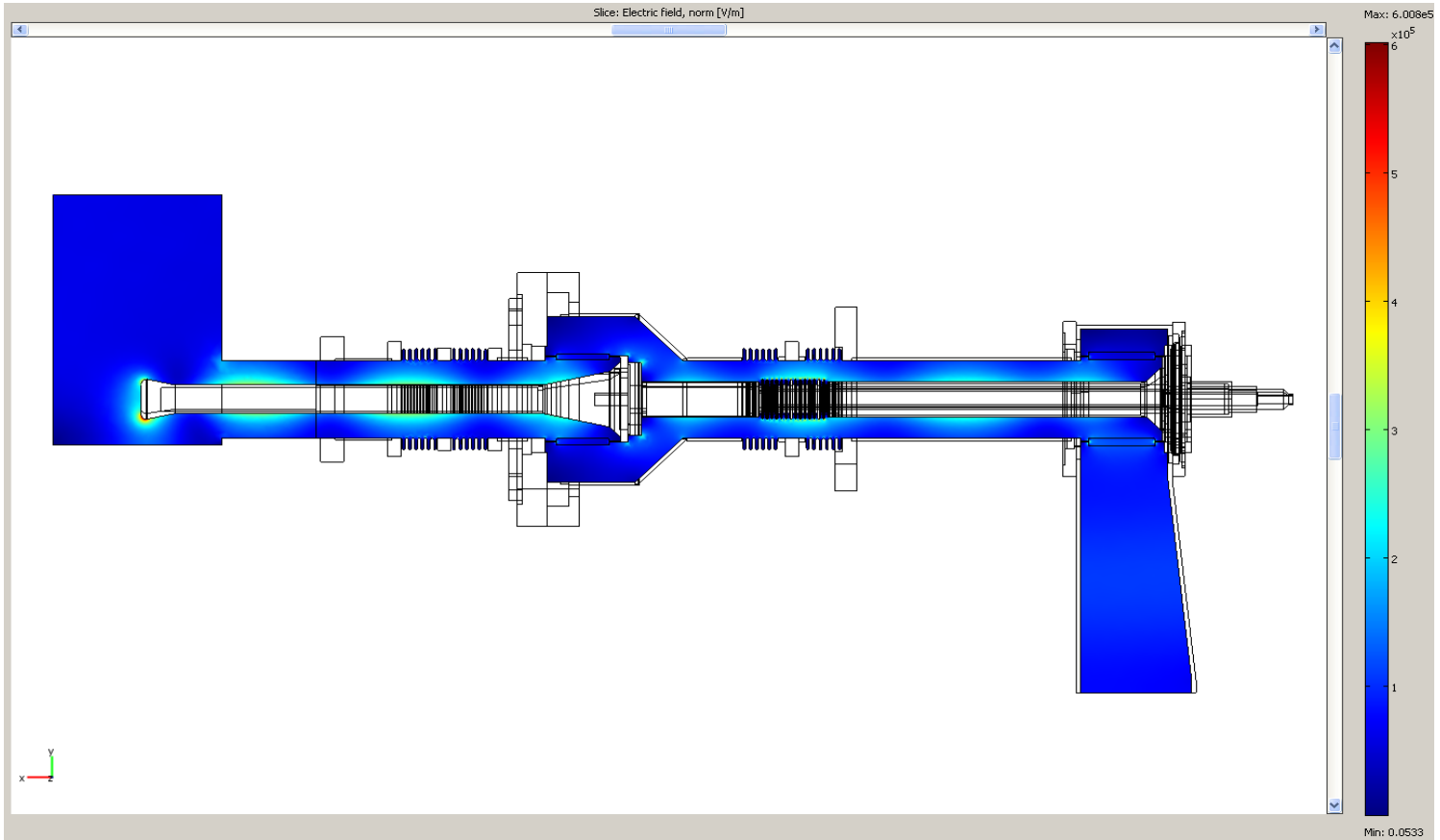
- Iterative RF-thermal multiphysics solve is carried out

Key Factor

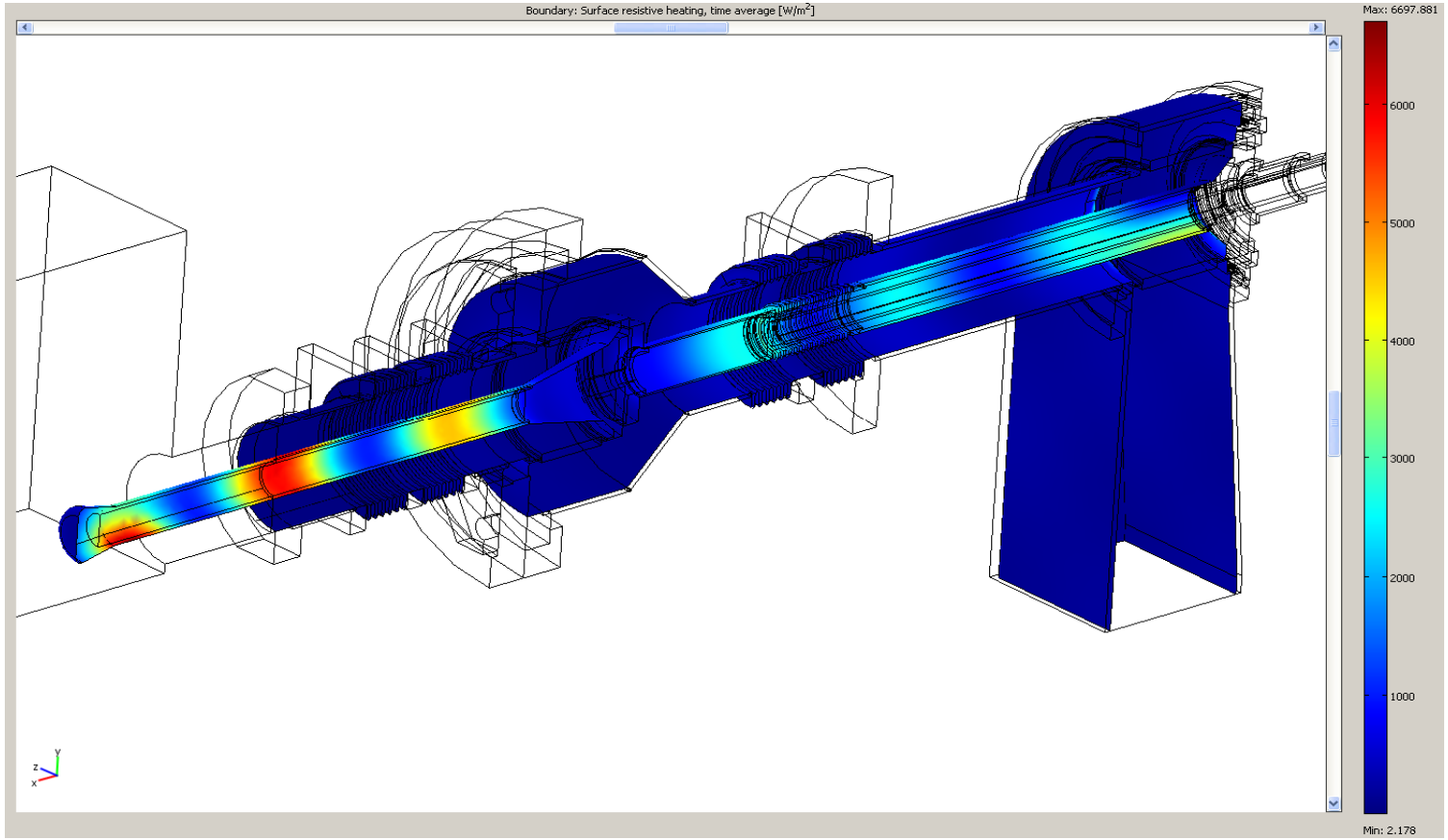
- Copper electrical conductivity changes by 3 orders of magnitude ‹100 kelvins
- Models variation of ALL MATERIALS with temperature
- Particularly temperature-dependent copper properties in RF solve
- Results in correct calculation of expansion of inner and outer coaxial to obtain stress

- Structural model solved sequentially after RF-thermal solve

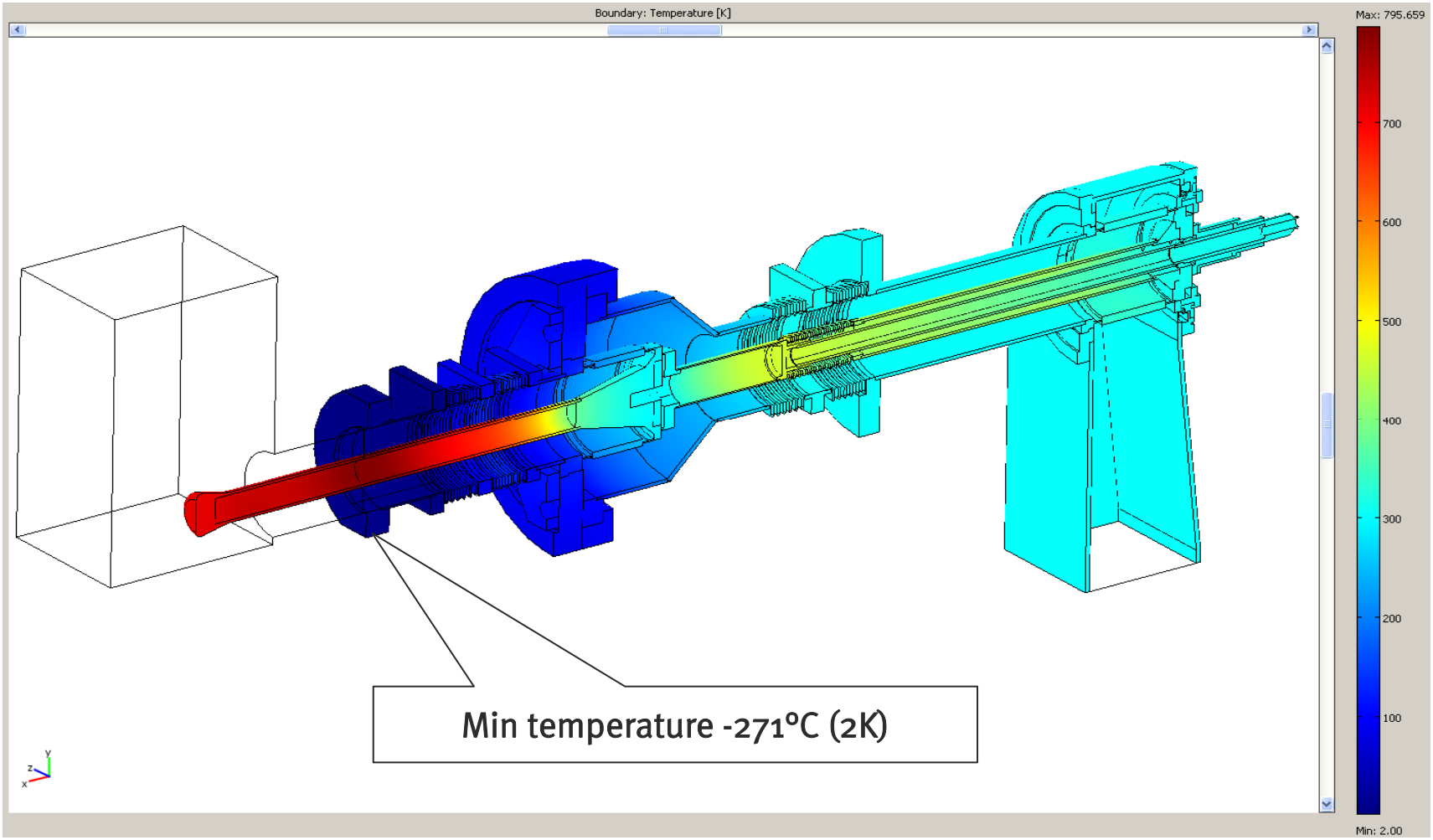
Electric field in the coaxial structure



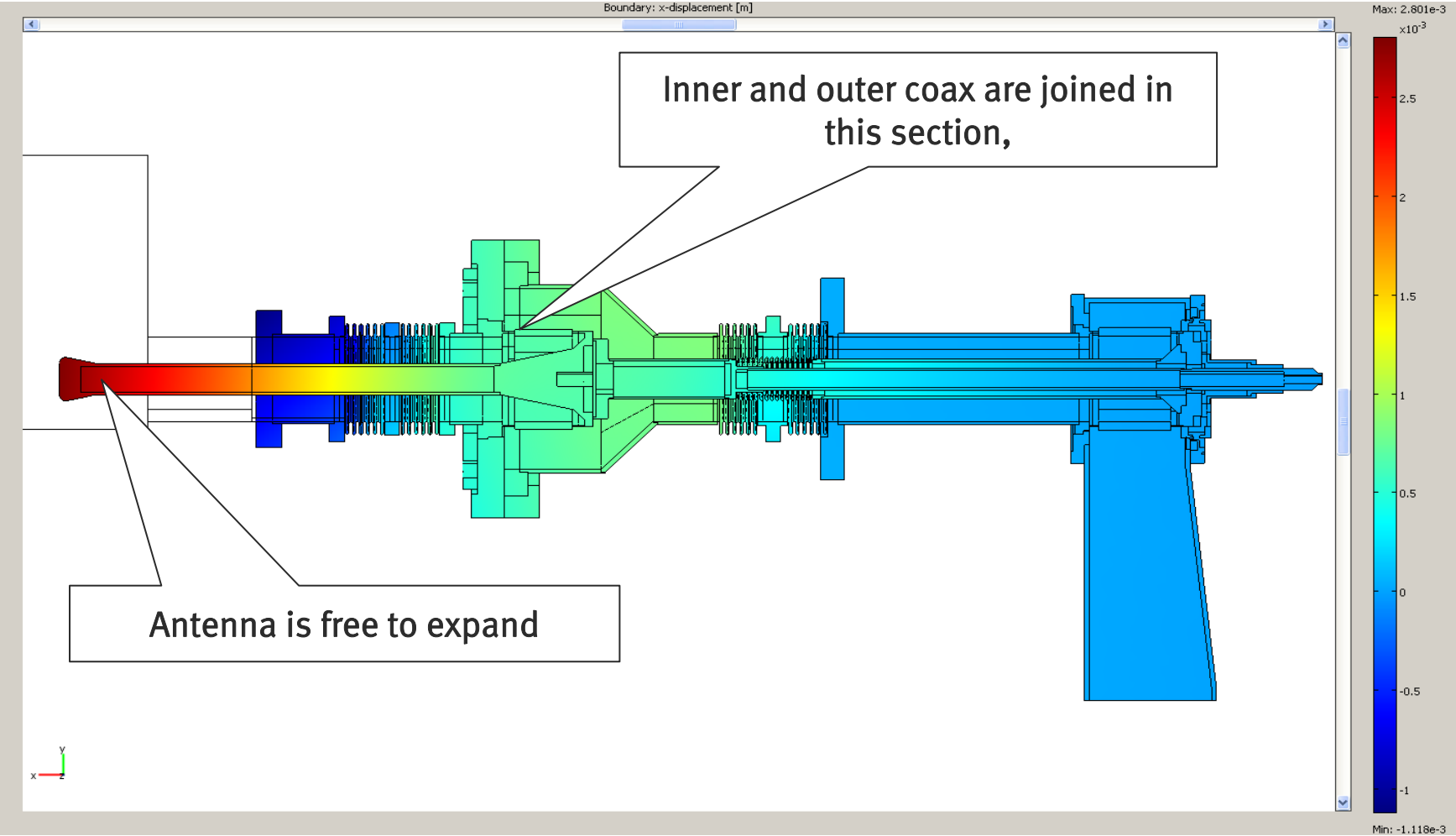
Resistive heating of copper surfaces excluding components interfacing with ceramic



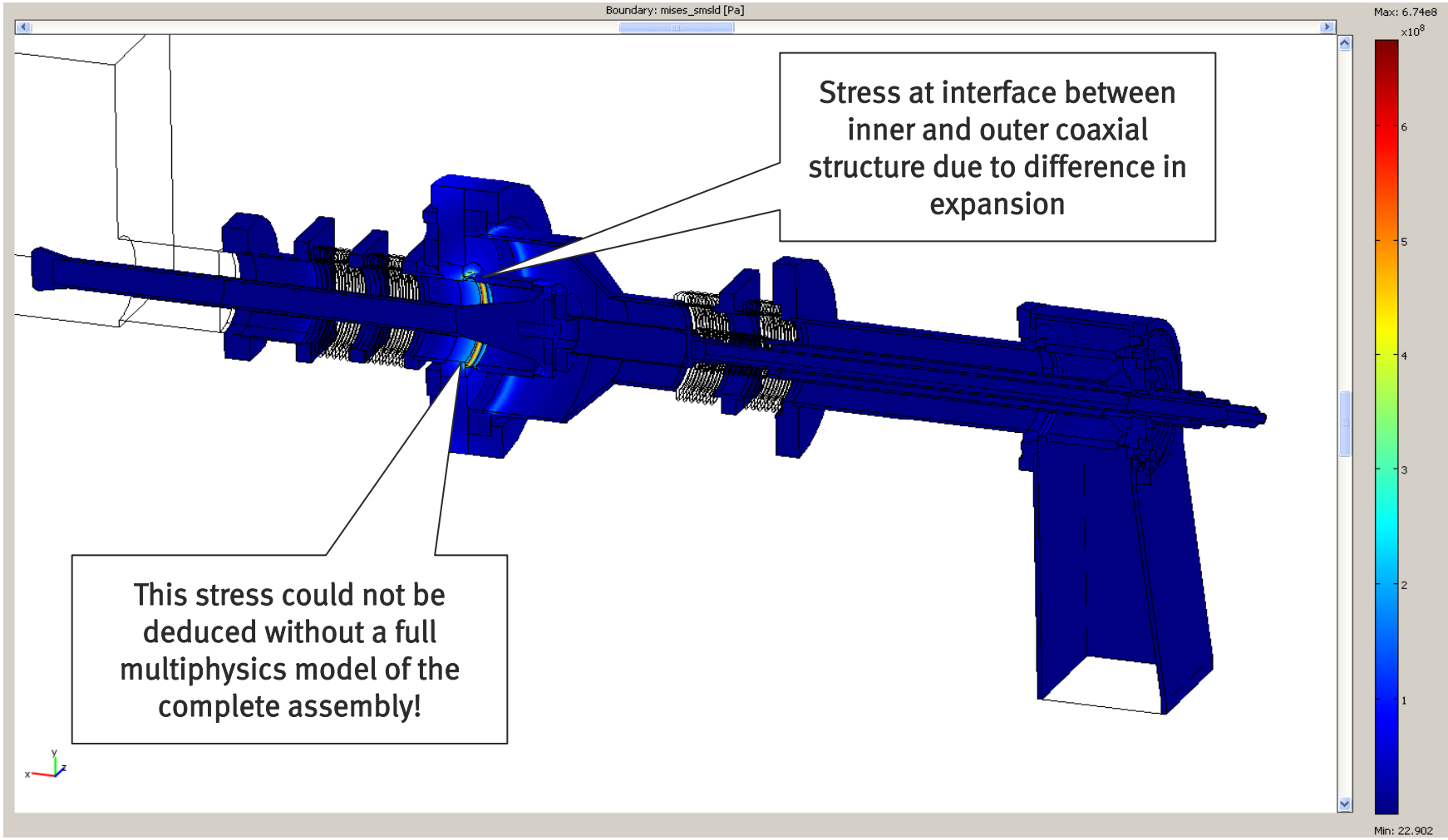
Iterative Multiphysics thermal analysis



Sequential structural solve
X axis displacement



Von Mises Stress of complete assembly



Microwave comminution of mineral ores

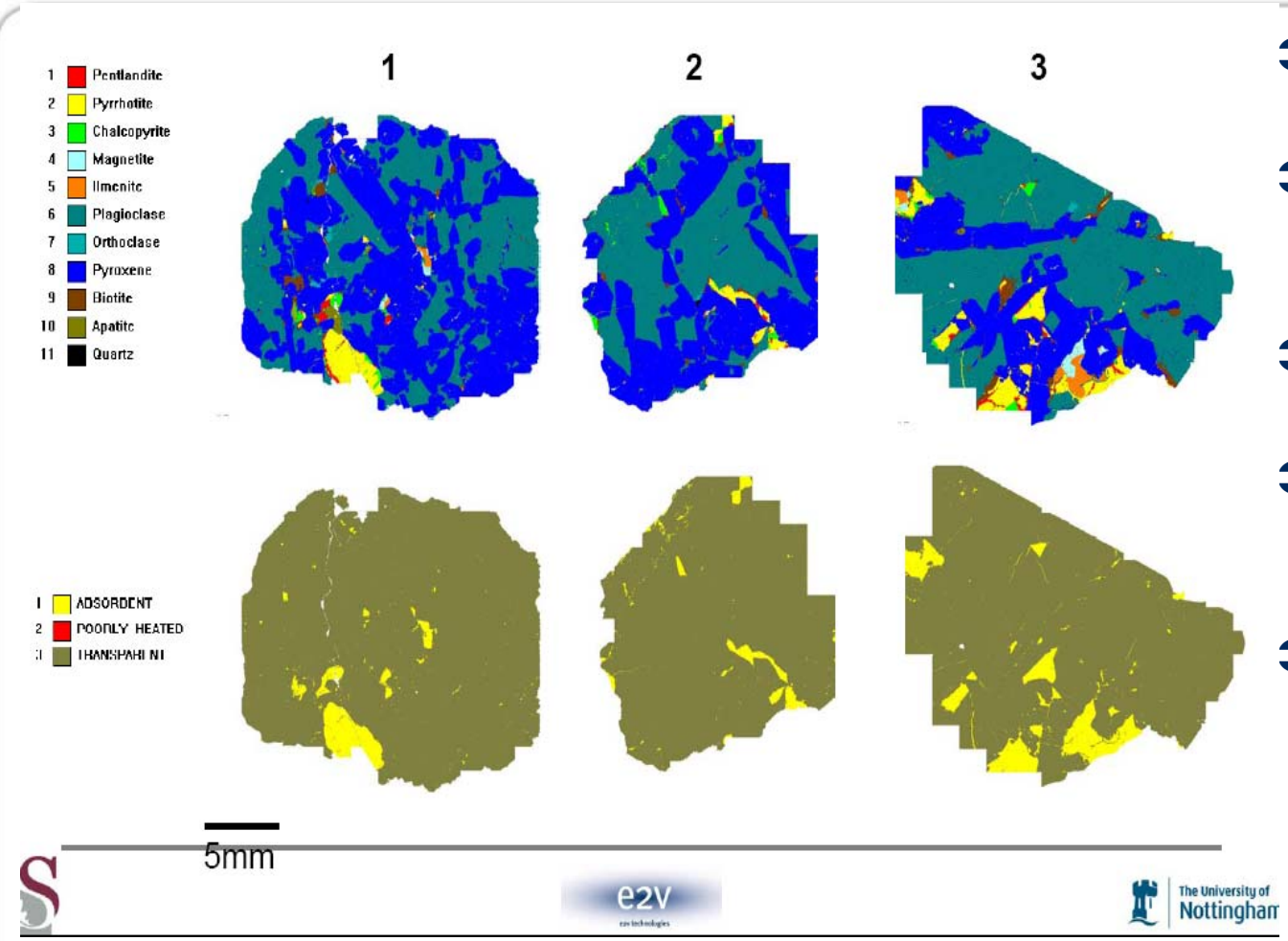
- Between 3% to 5% of the World's generated electrical energy is used to extract minerals from ore.
- Minerals are liberated through size reduction in multiple stages
- Size reduction is carried out in crushers and grinding mills
- Grinding is highly inefficient with less than 1% of the total energy input giving rise to new surface area
- Due to the scale of grinding processes (up to 275,000 tones per day) small improvements in efficiency offer a step change impact on process economics and environmental impact

Very large pieces of equipment

Ball mills for grinding mineral ore

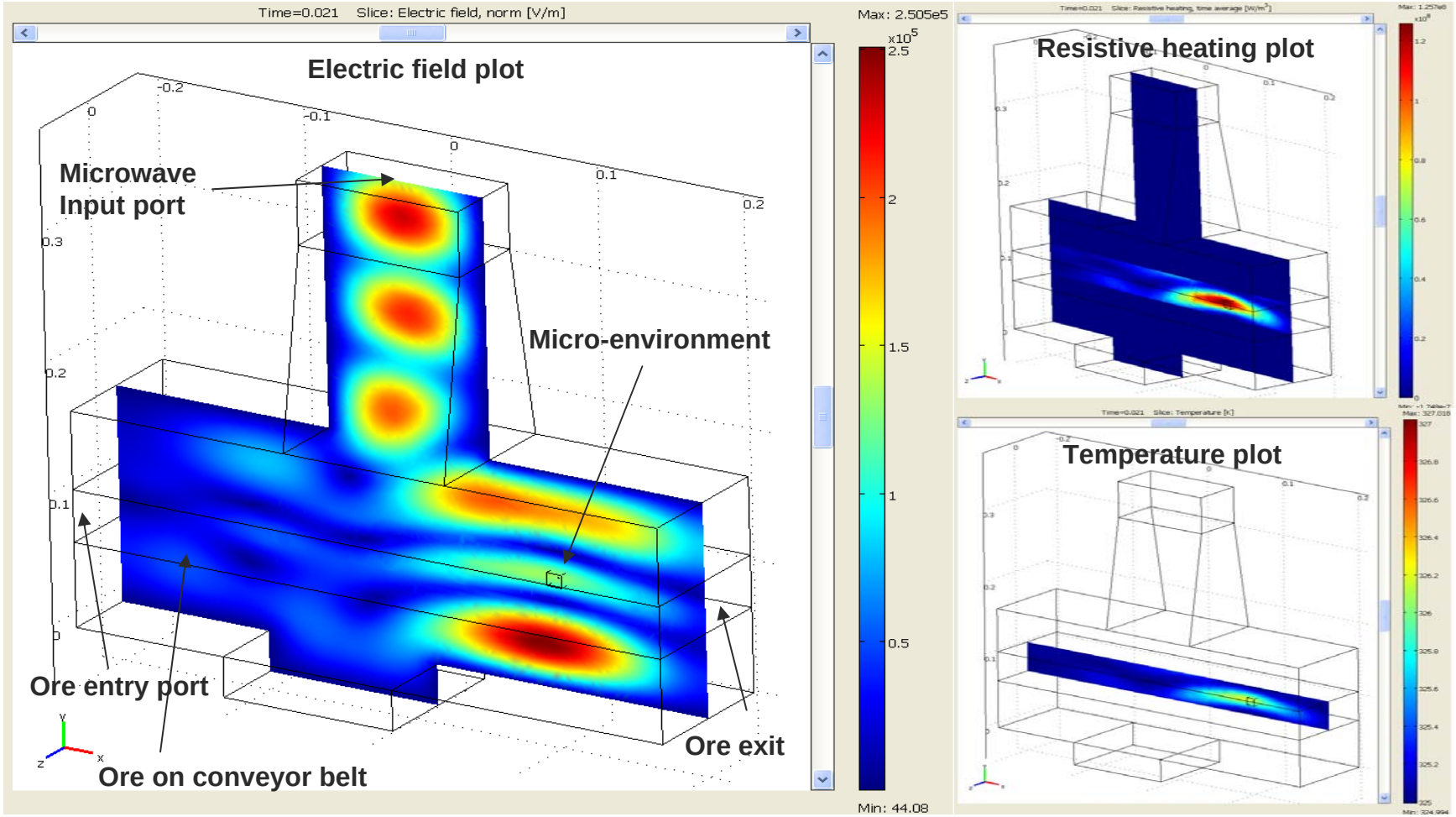
Very large pieces of equipment

Microwave-assisted comminution of mineral ore

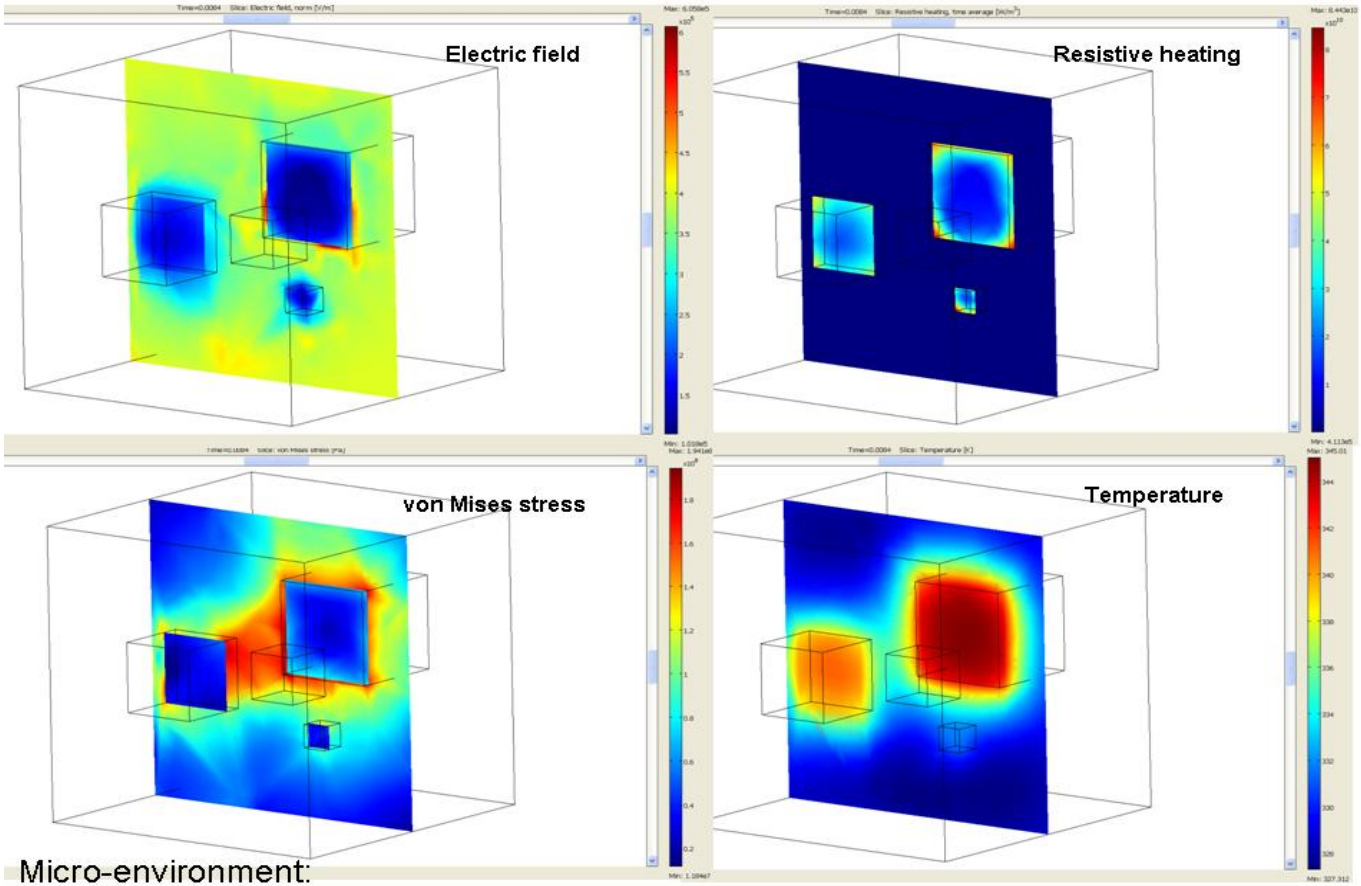


- Valuable mineral (yellow)
- Microwaves selectively heat the mineral particle
- Rest transparent to microwaves
- Rapid heating and causes expansion of mineral
- Result: mechanical stresses which aid mineral extraction

An example microwave applicator



Simulation results in the micro environment

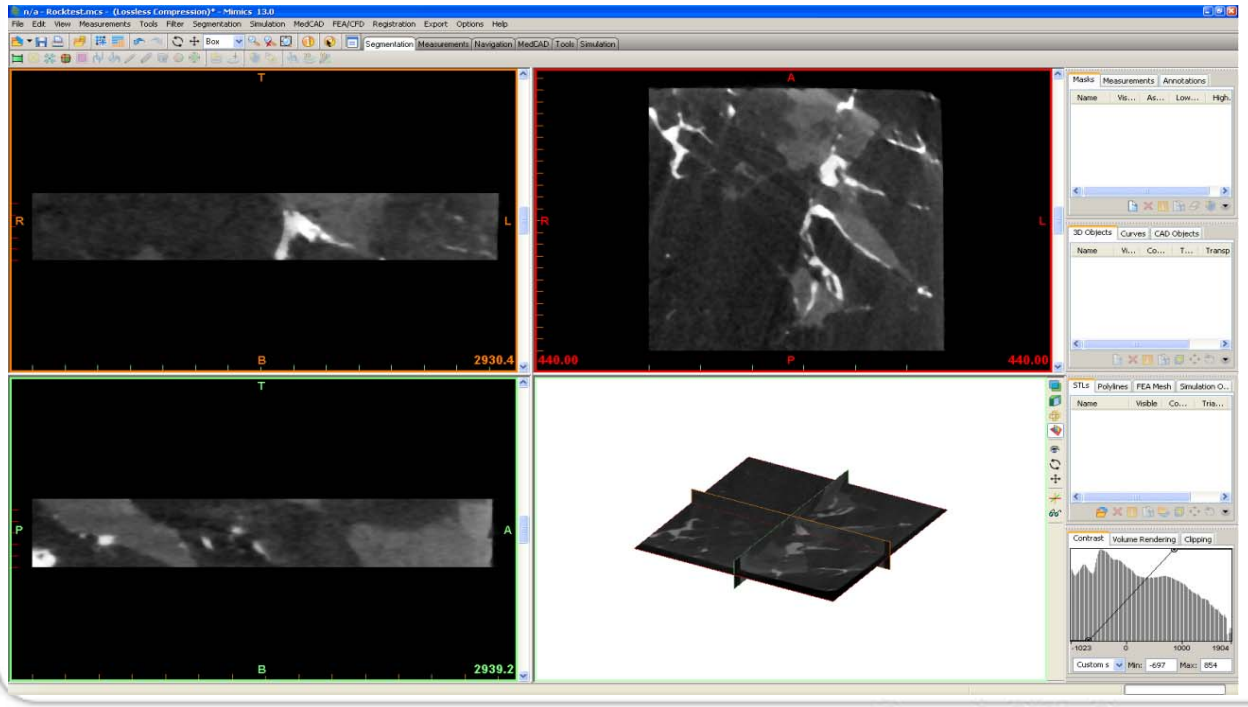


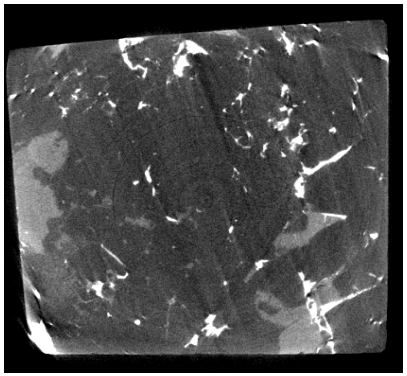
Micro-environment:

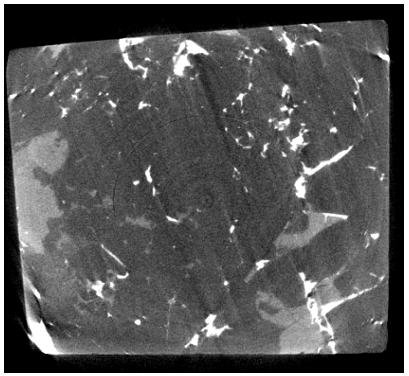
Bounding cube each side 630um, Cube 1: 200um, Cube 2:150um, Cube 3: 100um, Cube 4: 50um

More about the macro-micro environment

- X ray micro CT scans
- Large number of 2D image slices
- Materialise can interpolate between these 2D slices to create 3D geometry

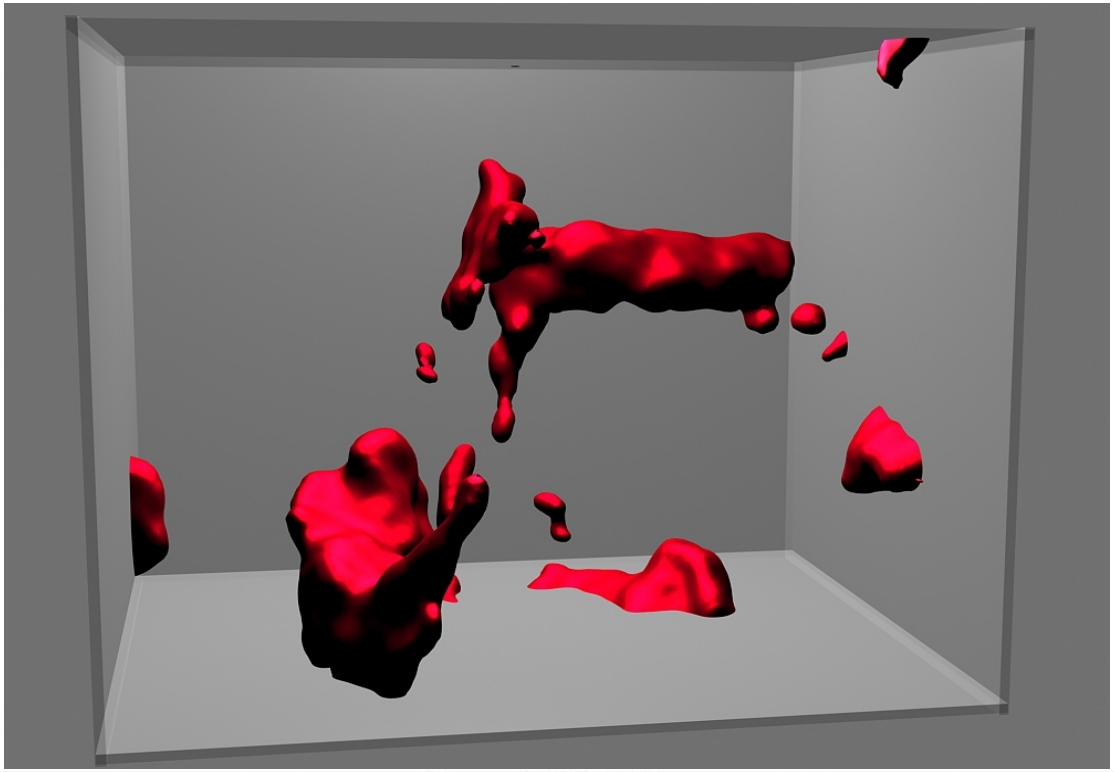






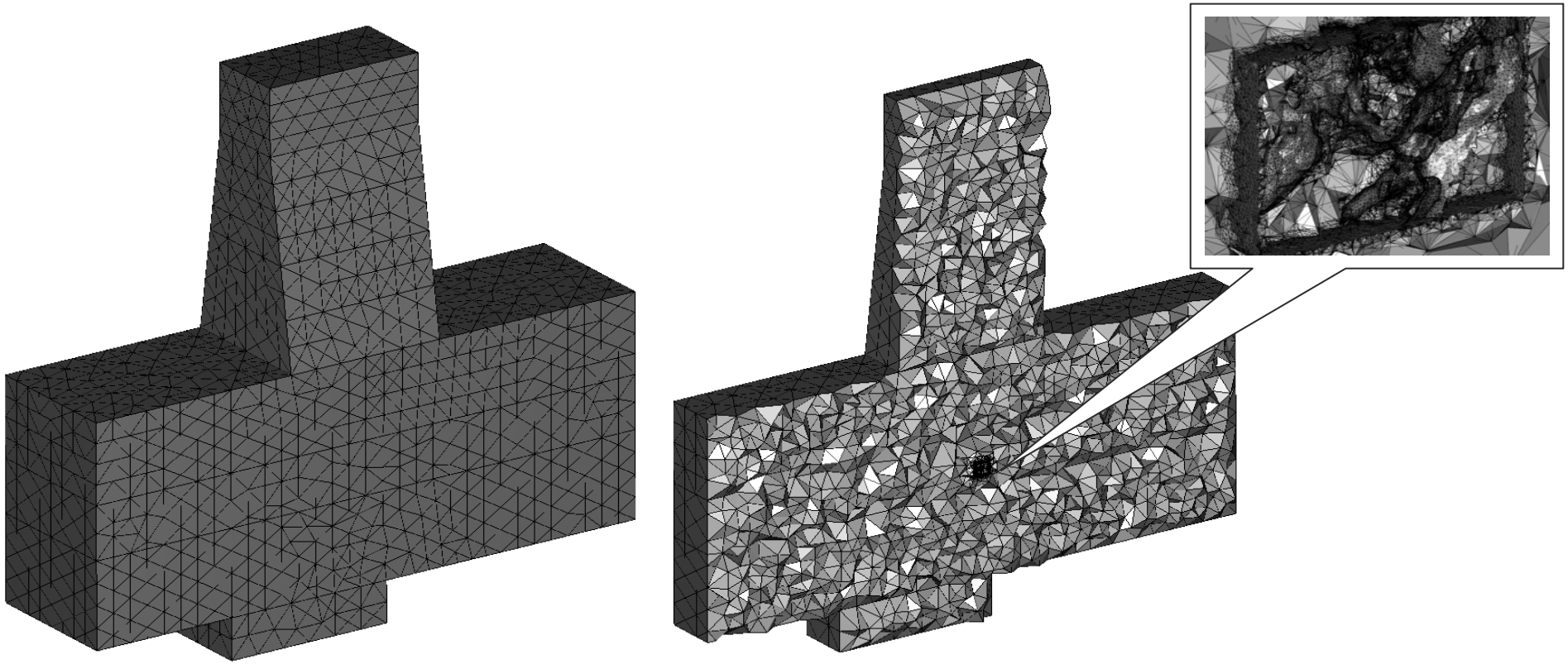
Reconstructed and segmented pieces of mineral ore

- A simple segmented 3D reconstruction of a piece of the mineral ore
- Materialise software used to combine segmented model and applicator model

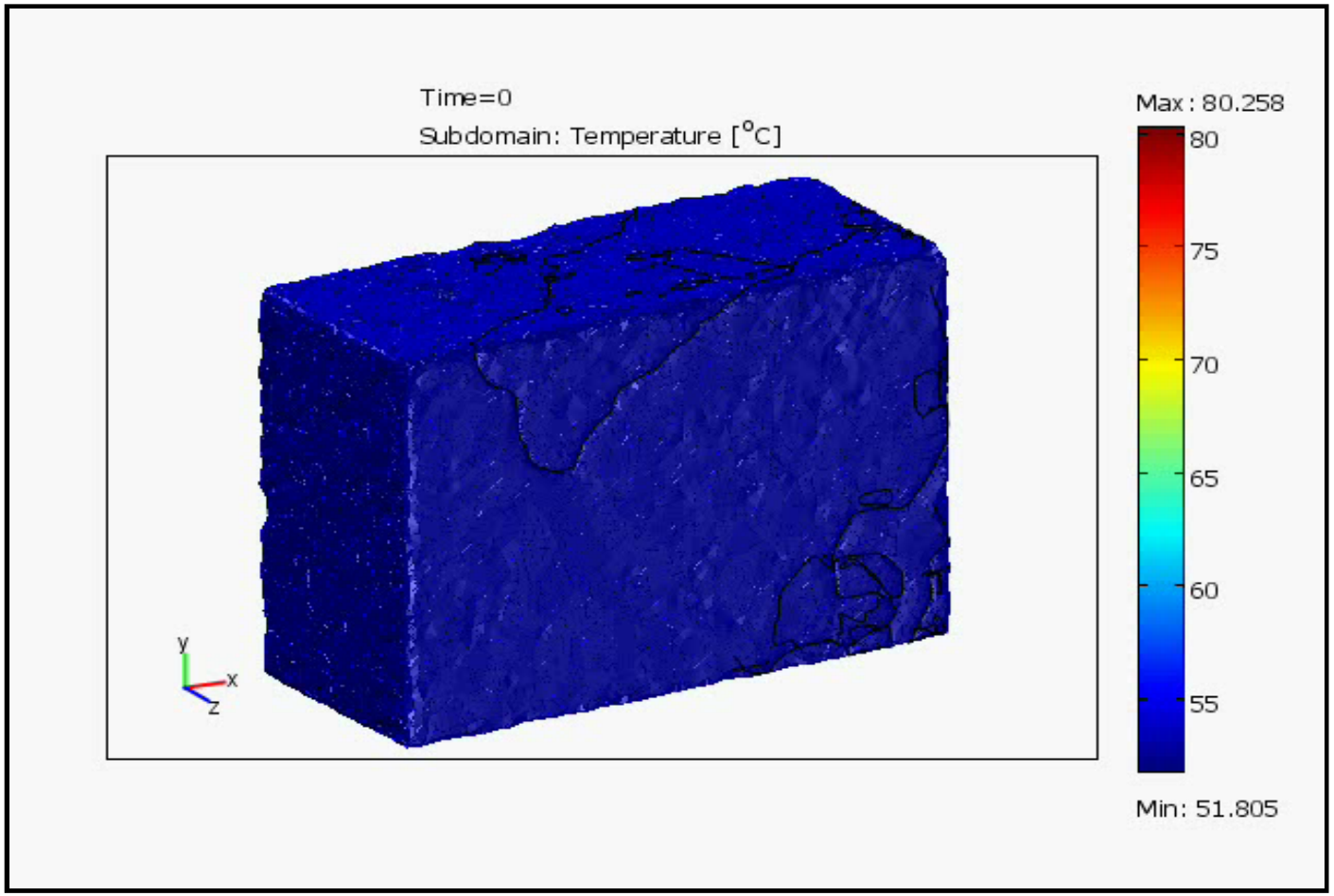


Import mesh into COMSOL Multiphysics

- Mesh is imported into COMSOL Multiphysics
- Now we have macro and micro environment for analysis



Heat Transfer Analysis – temperature results microenvironment

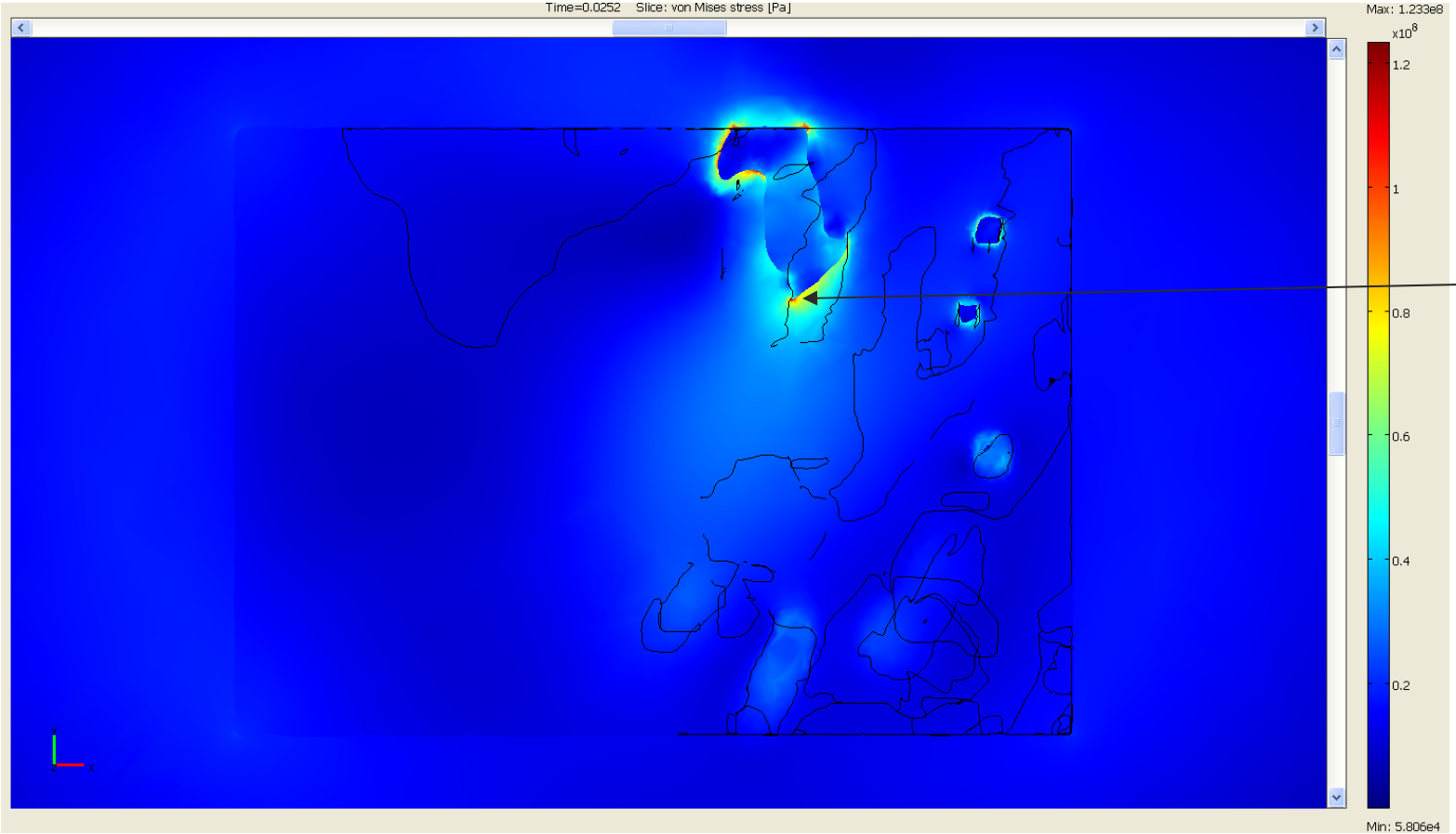


➲Heat dissipation in micro environment 500kW microwave pulse for 0.0126 seconds

➲Localised heat on outer surface due to the presence of large lump of pyrite

Click to play

Von Misses stress



➲Boundary fractures occur at 30 MPa

➲Maximum predicted stress 120 MPa

Next stage: Process modelling

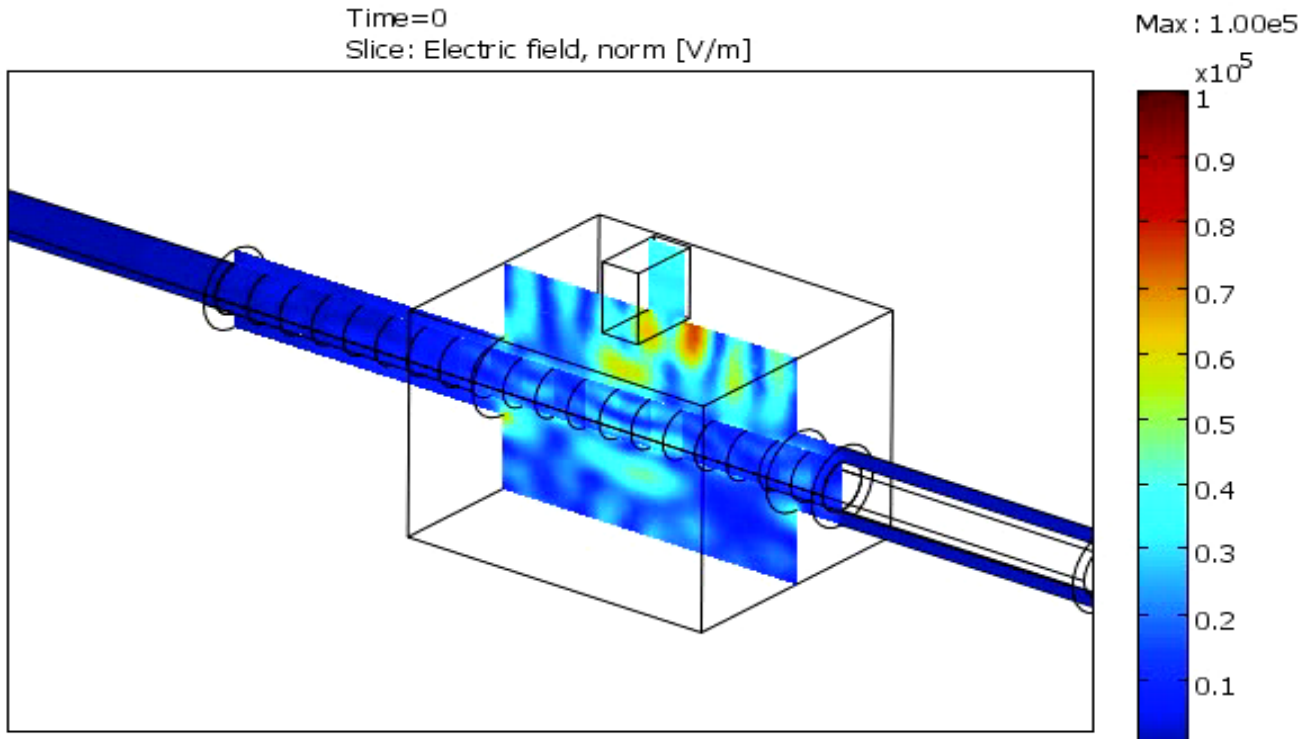
- The product is normally moving

- Mineral ore on a conveyor belt
- Mineral ore composition will not be uniform
- Mineral ore size will vary

- How can we simulate this?

- Moving mesh.

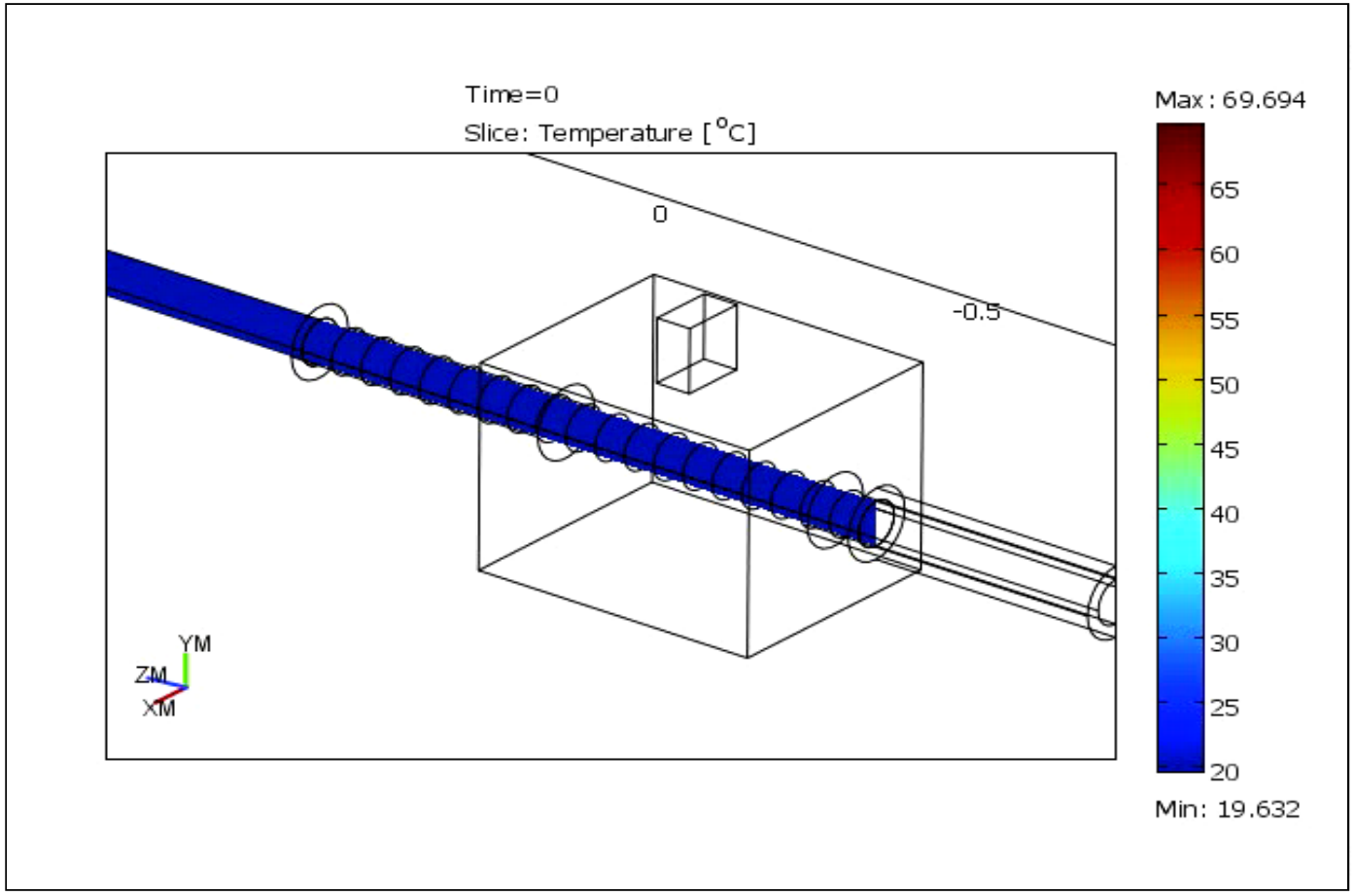
Electric field in a multimode cavity with varying moving mineral ore properties



- Variable load moves through a multimode RF cavity
- Each block has differing dielectric properties

Click to Play

Temperature change in a multimode cavity with moving varying mineral ore properties



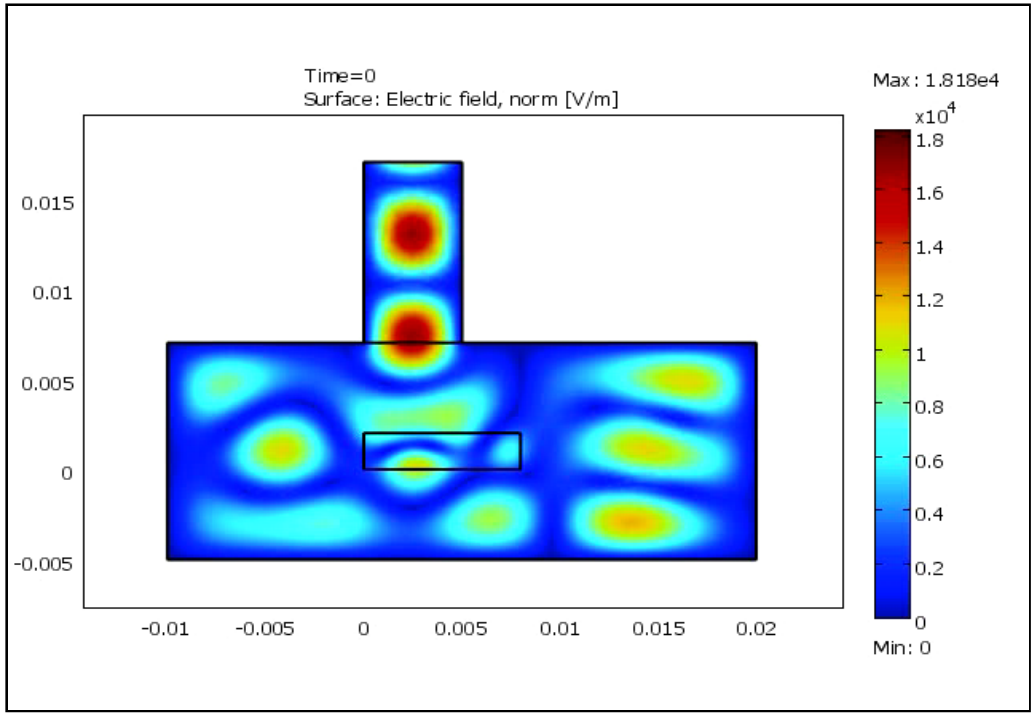
Click To Play

Finally a food application

- Moisture transport in a porous media.
- I have covered, RF thermal and mechanical interactions
- This example looks at removing moisture from a porous sample in a multimode cavity
- Ryan Renshaw will present a detailed paper covering this topic at 1030 on Friday

Porous media advanced Multiphysics model (RF food processing)

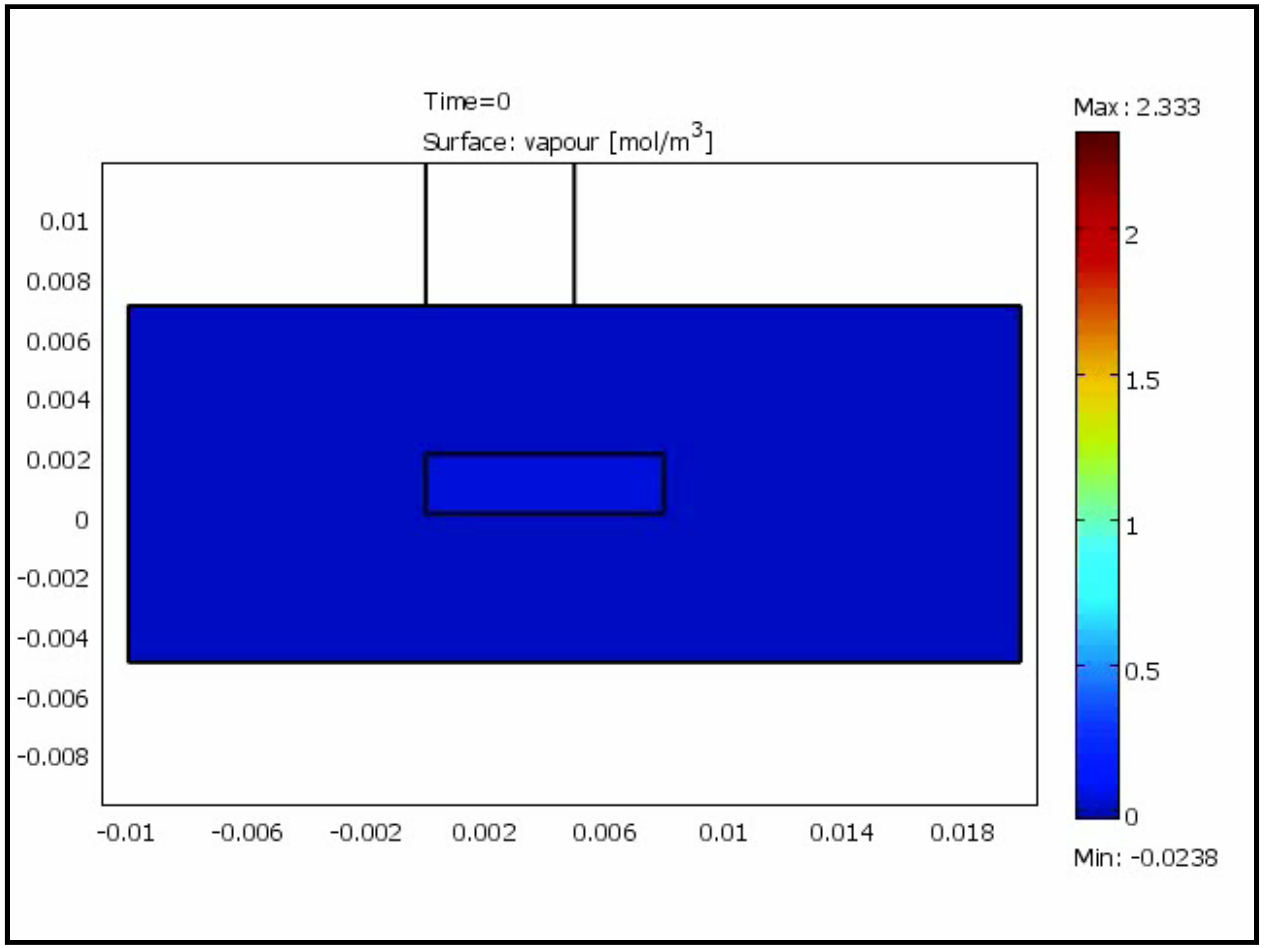
- Model includes RF, Navier Stokes, Darcy's Law, heat transfer, evaporation physics, convection and diffusion
- See Ryan Renshaw's user presentation at 10:30 on Friday 16th October



- Air flow of 3ms^{-1} from left to right
- Air inlet temperature = 60°C.
- Again multi mode field patterns change as moisture is driven out (dielectric change)

Click To Play

Water vapour transport



Click To Play

Closing Comments

- We have seen a few of the diverse ways e2v has started to use COMSOL
- It is allowing us to view our processes in a different way
  - Resulting in improvements
- It is enabling our engineers and scientists to examine the full application, not just the microwave or RF tube
- Resulting in:
  - Complete product solution - with much added value
  - Expected considerable growth in business

Thank you to:

- COMSOL for the opportunity
- e2v for the rope
- Steve Hurrell for the original modelling support
- Ryan Renshaw for doing most of the modelling
- Professor Sam Kingman University of Nottingham (Mineral comminution)
- Carl Beard of ASTec Daresbury UK for use of the coupler example