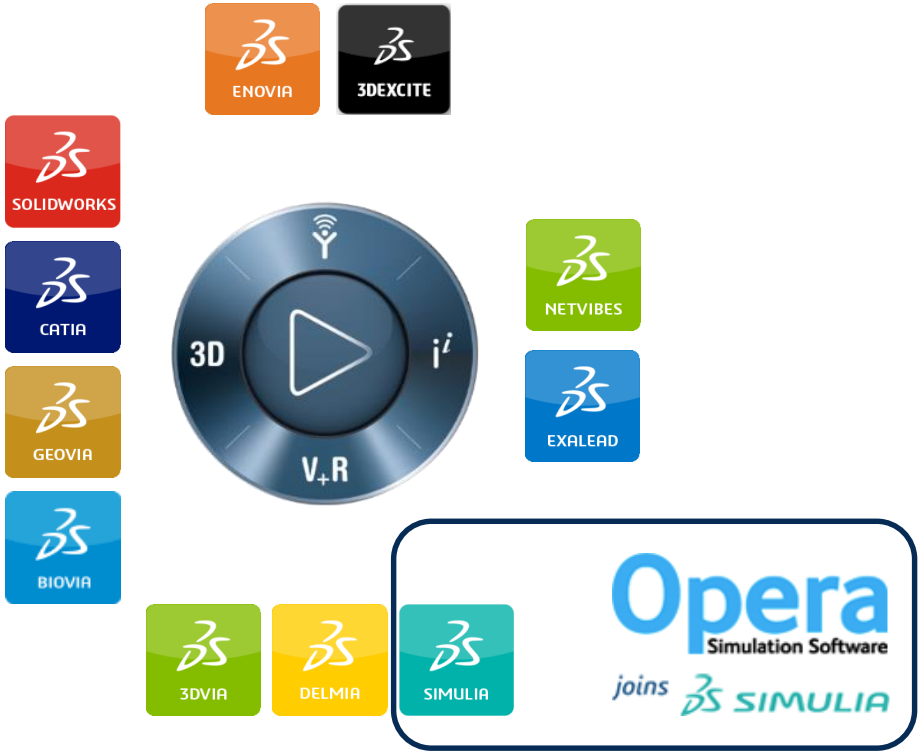

3DEXPERIENCE®

# SIMULIA Opera™: experience

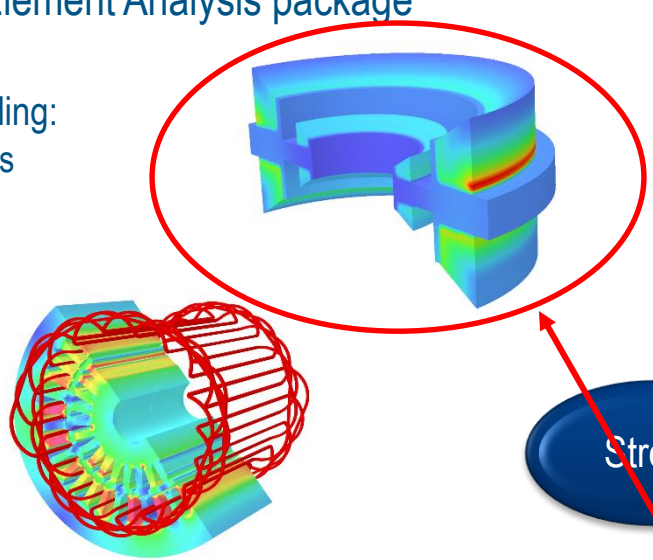
Chris Riley, Opera Software

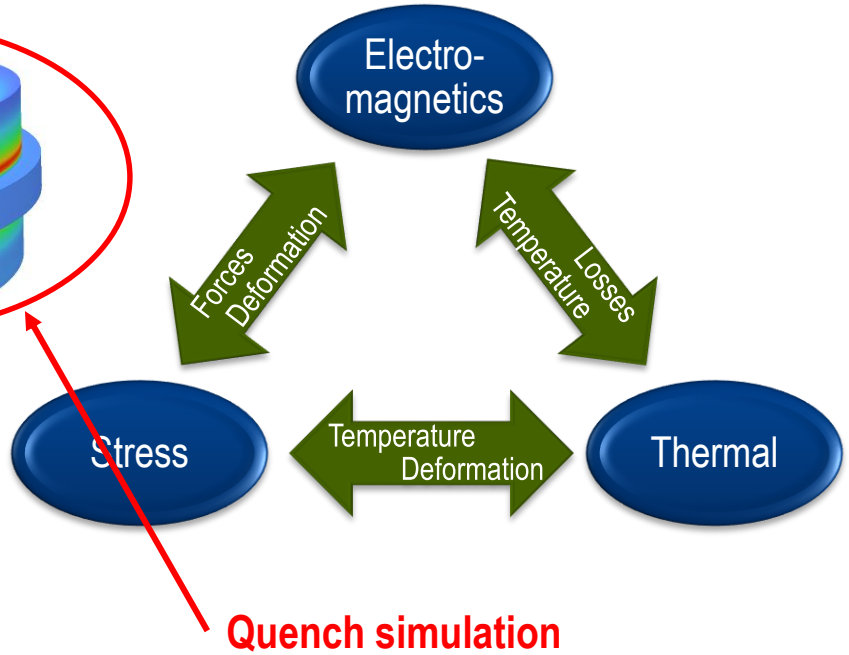
# The **Dassault Systèmes** brands



# Opera

- Opera is a Finite Element Analysis package
  - 2D and/or 3D
  - Multiphysics including:
    - Electromagnetics
    - Space Charge
    - Stress
    - Thermal
- Developed for:
  - Accuracy
  - Capability
  - Reliability
  - Speed
  - Ease-of-use
- Sold direct and by a network of distributors & resellers





# SIMULIA Opera Quench

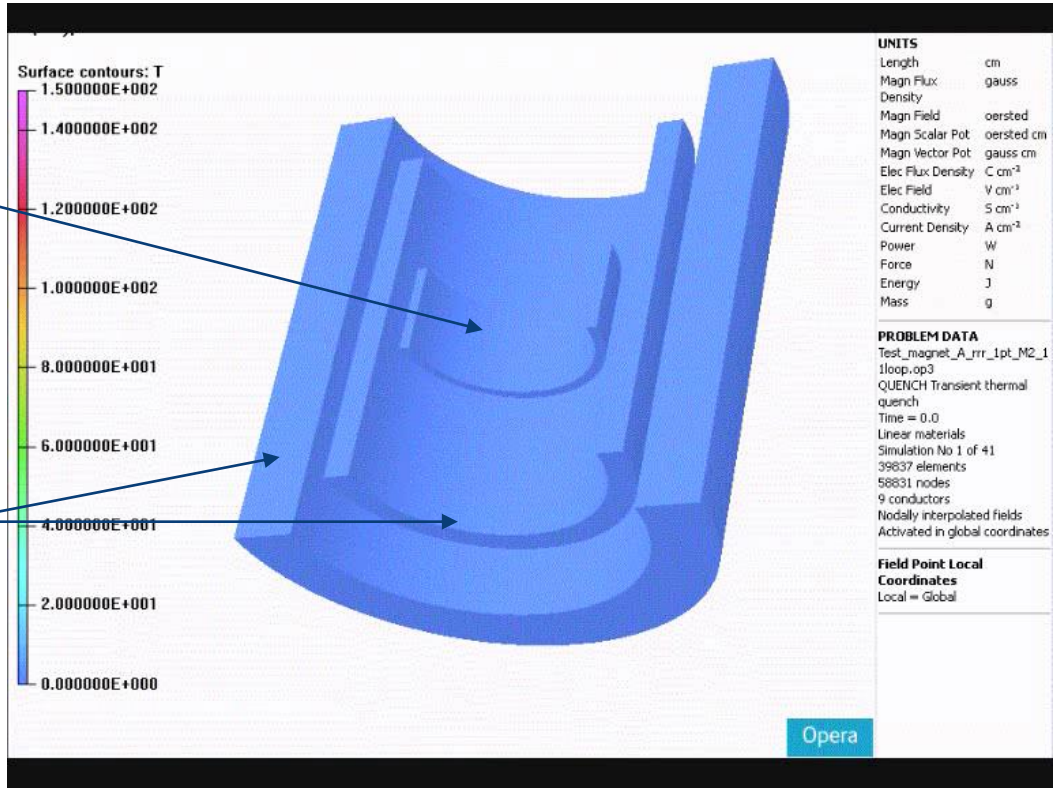
- Developed during 2 collaborations to model quench in LTS magnets
  - Opera, Siemens Magnet Technology, Oxford Instruments
  - Opera, Oxford Instruments, University of Southampton (Impdhama)
    - Part funded by Innovate UK

- Coupled transient electromagnetic, circuit and thermal finite element simulation
  - Macroscopic material models
    - Expressions made from constituent material tables and volume fractions
      - Wire Cp = (NbTi_Cpn(T)*#NbTiFac*#NbTiDen +Cu_Cp(T)*#CuFac*#CuDen)/#BulkDen
    - Or measured wire data

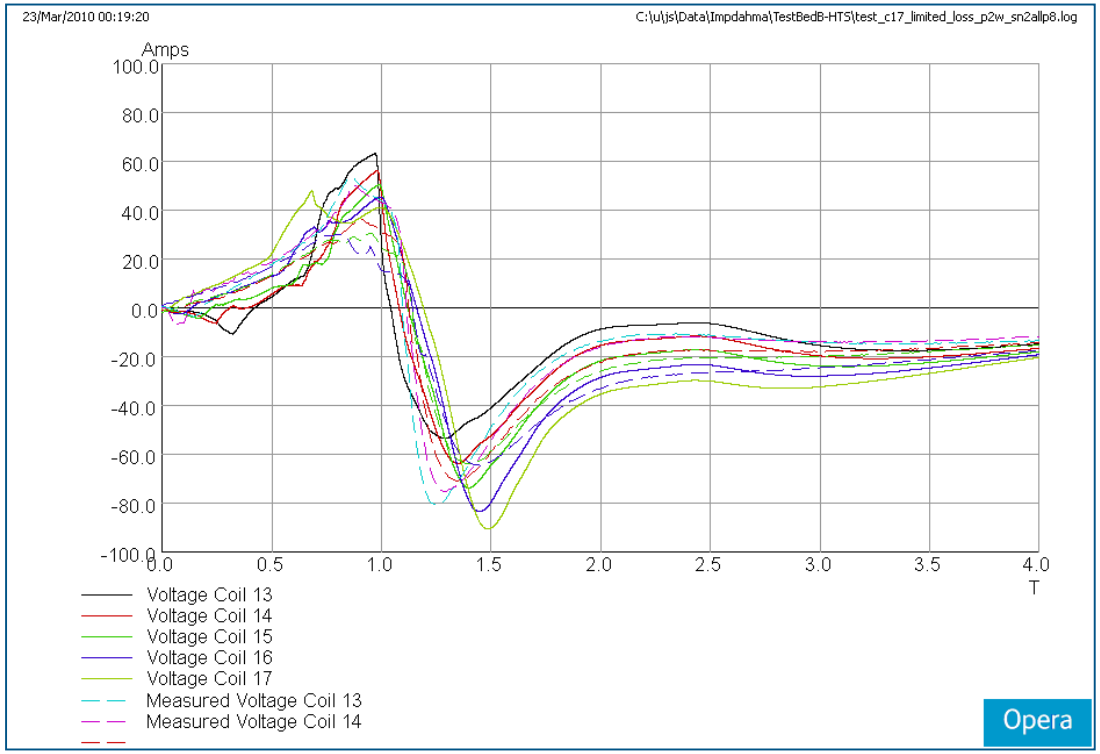
# Evolution of temperature rise in a test magnet

HTS insert

Multiple LTS coils



# High accuracy for electrical circuit voltages and currents

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# SIMULIA Opera™: Proposal Multiscale modelling

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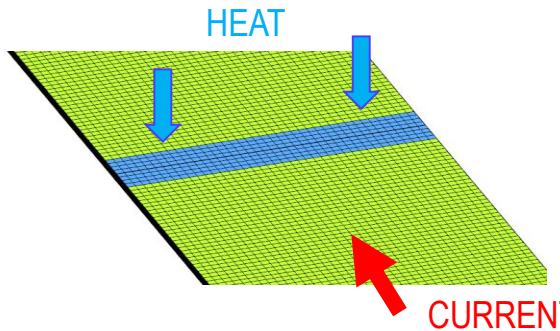
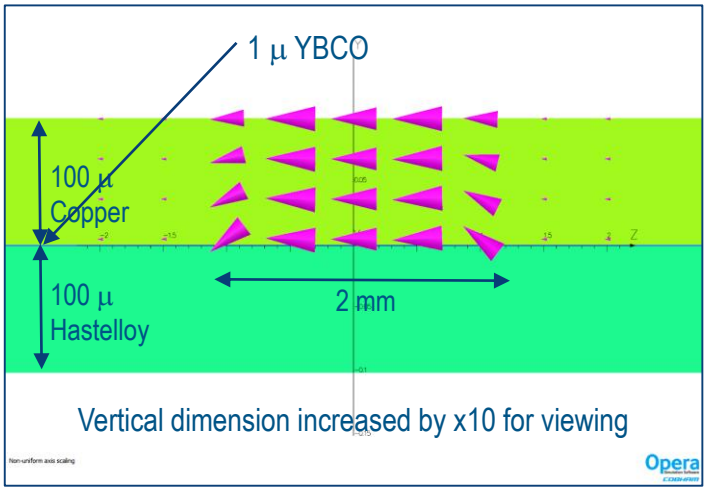
# Issue for an HTS magnet

- Good solution in Impdhama depended on:
  - Accurate material measurements by University of Southampton Cryogenics Department under a large variety of operating conditions
  - Accurate details on test magnet construction used by Oxford Instruments
  - Some fine tuning of Opera model through comparison with measurements
    - Improved estimation of rate dependent losses in LTS
- What happens when designing a new magnet?
  - Manufacturer's supplied wire / tape properties data
    - Is it sufficient?
    - Does it cope with current sharing?
  - Magnet construction details

# Proposal (1)

- Multiscale modelling
  - Simulation at both micro and macro scales
  - Partly based on a suggestion made by Stefan Russenschuck, CERN
    - Simultaneous solution
- Separate simulations
  - Stage 1: Simulate single tape / small bundle of tapes
    - Use material data for each constituent



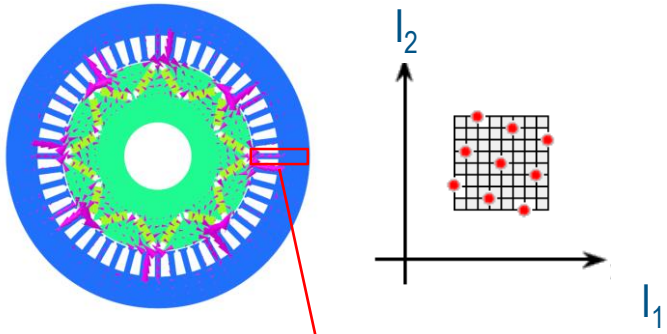



# Proposal (2)

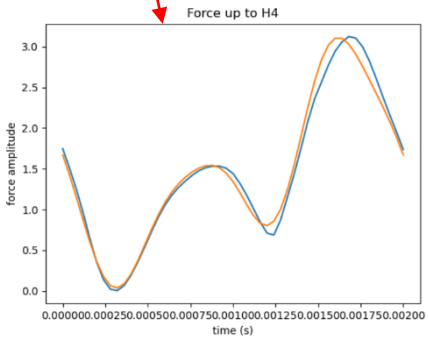
- Stage 1 (continued): Use Design of Experiments to characterize properties at tape level
  - $f(B, \frac{\partial B}{\partial t}, T, J, \dots)$
  - Look up tables?
    - Expensive computationally
  - Derive representative functions
    - Example: force characterization in motors $\Rightarrow$ system level mechanical models (EDISON project)
  - SIMULIA Isight
    - $FS_c = K + a.I_d + b.I_q + c.I_d^2 + d.I_q^2 + e.I_d.I_q + f.I_d^3 + g.I_q^3$

# Proposal (3)

- Model run at multiple currents
  - DoE




- Force v time at each current combination
  - Periodic




- Expression for each Fourier component
  - $frad_{b4} = -0.0880 + 0.00112 \cdot I_q - 3.60 \cdot 10^{-6} \cdot I_d I_q - 2.09 \cdot 10^{-8} \cdot Id^3$

# Proposal (4)

- Stage 2: Macroscopic level model of magnet using SIMULIA Opera Quench (or similar)
  - Use characteristic representations for wire / tape in coils

- Advantages:
  - Enables new wire / tape / winding constructions to be explored
  - DoE can be run in parallel
  - Fast matrix assembly for Quench simulation

# Proposal (5)

- Partners:
  - Software developers
  - Experienced modellers at wire / tape level
  - Test coil manufacturer
  - Wire / tape manufacturers?
  - Measurement facility