

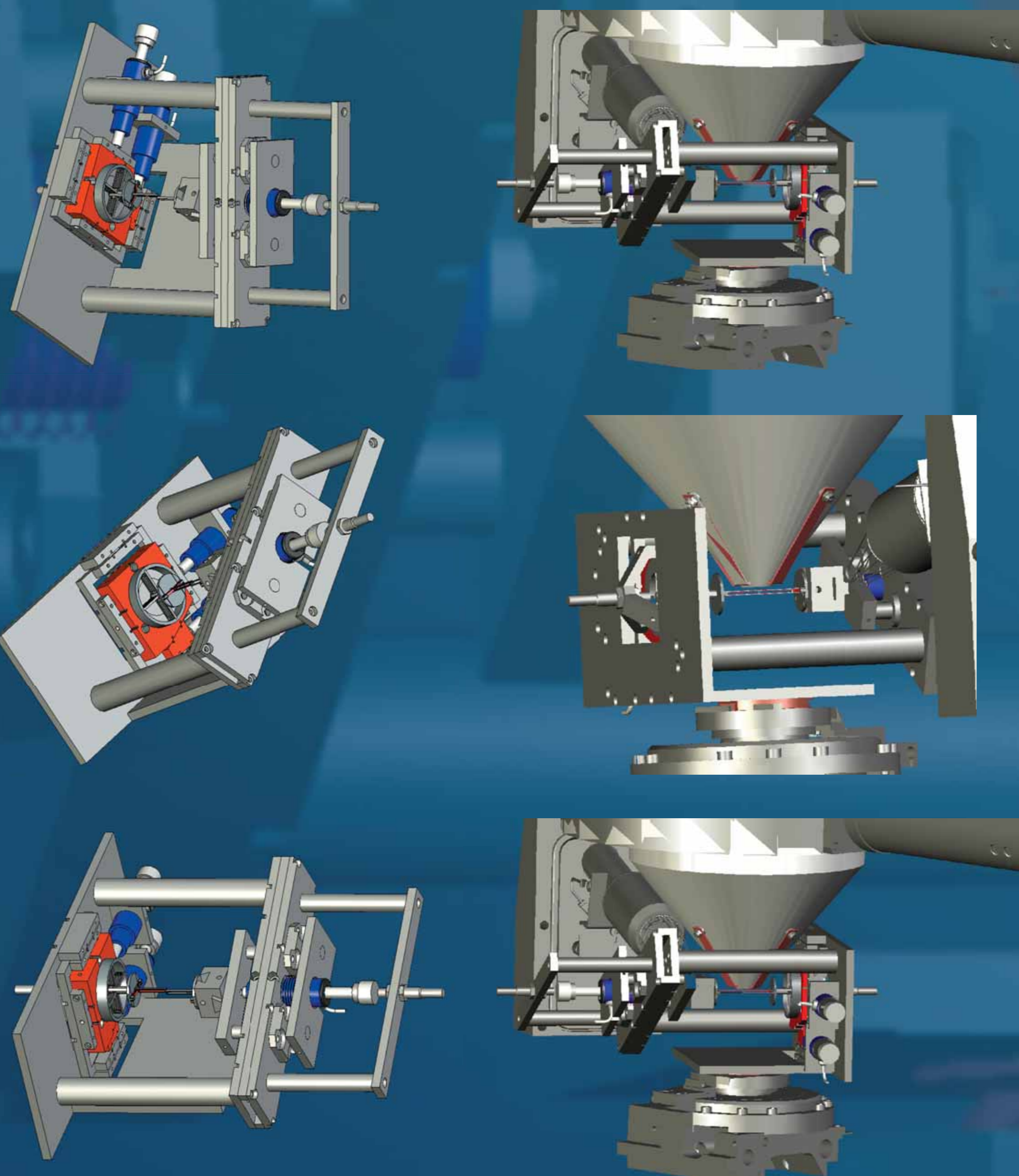
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Goals

- Measurements of forces from 0 to 1N with a μN sensitivity
- Material testing at small scales
 - Micro tensile
 - Micro compression
 - Shear
 - Nanoindentation
- Force feedback on tool tips
- In-situ strain measurement using the SEM and Digital Image Correlation

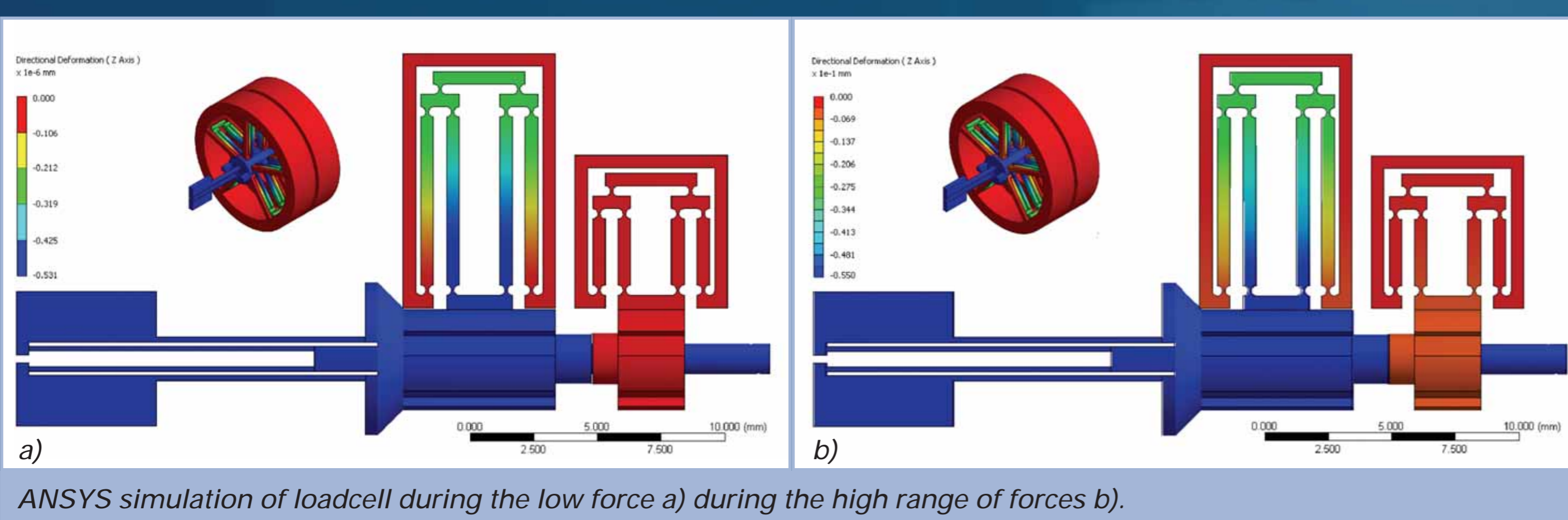
Design

- Sketched in SolidWorks, optimised in ANSYS
- Easy fit in SEM stage
- Control and measurement in 3 orthogonal directions.
- Displacement resolution of 1nm over 1 μm range & 20nm over 5mm
- No lead wires as they induce stiffness corrections
- Vacuum compatible
- Four monoliths arranged in a star arrangement to counteract any torsion.
- No arcuate error out of symmetry conditions
- Based upon a symmetrical stress distribution, utilises elastic averaging to reduce the effect of machining errors or assembly on the linearity of the motion.

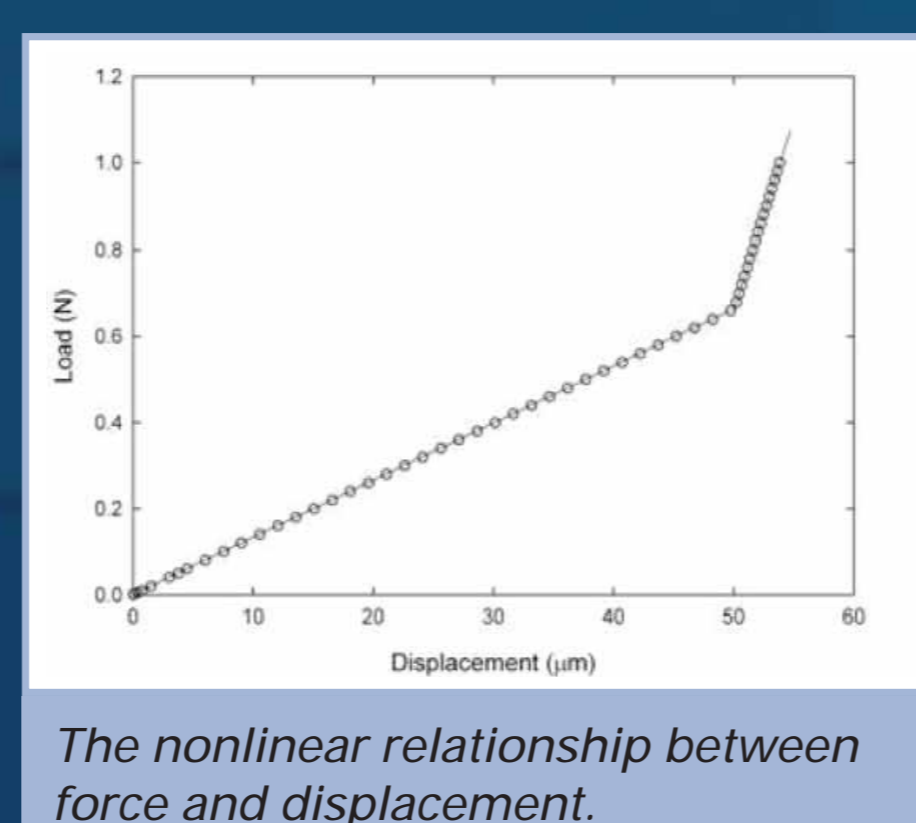


Two calibrated spring constants that bump into each other.

- Measurement of the displacement of a sensor with calibrated spring constant.
- The double load cell configuration achieves non-linearity between Force and Displacement, increasing the force measurement range:

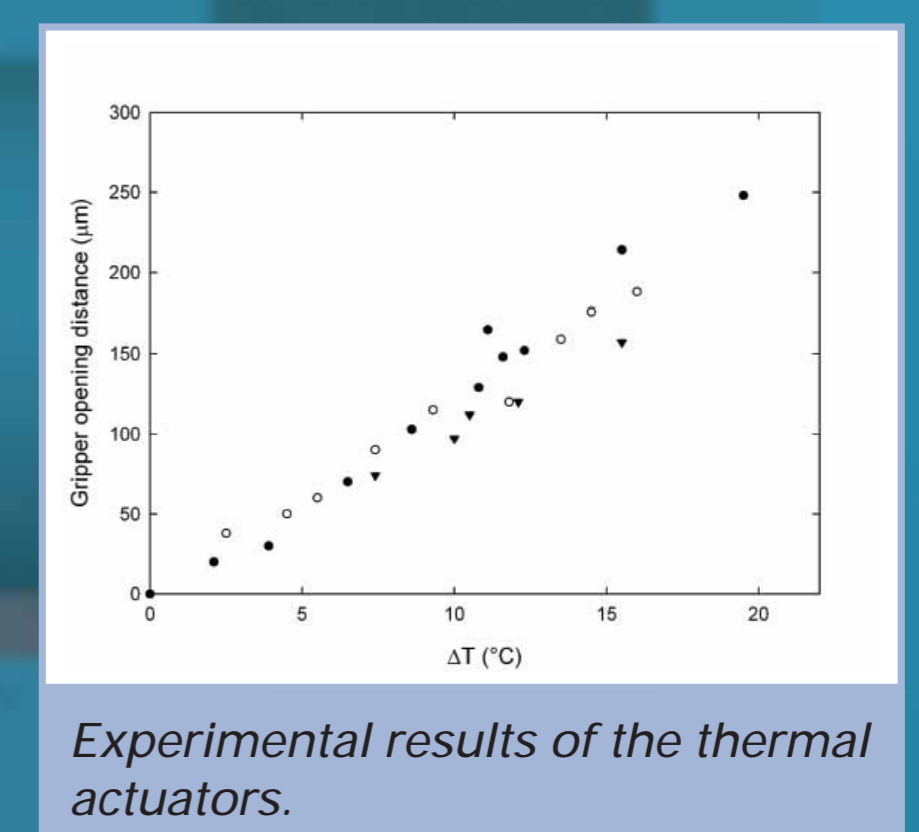
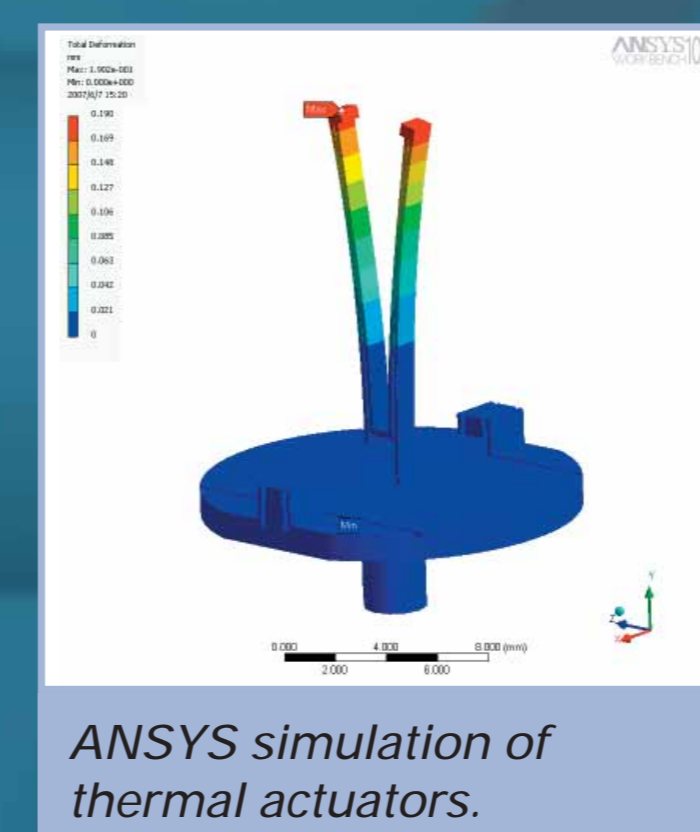


- Two groups of monoliths: One of low stiffness and the latter of high stiffness, upon contact stiffness becomes the sum
- Number of data points are limited by the displacement, this allows to increase the load while keeping the same relative sensitivity in the whole range



Thermally actuated micro grippers

- Grippers manufactured off-site (MML), mounted at NPL
- First experiments show good linearity, concept validated
- In just $\Delta T = 20^\circ\text{C}$, opening gap reaches 200 μm



Low hysteresis on movement

- Roller bearings done in silicon nitride. With low- to unexisting friction.
- X-Y movement aligned to avoid errors.
- Y movement 33% more accurate

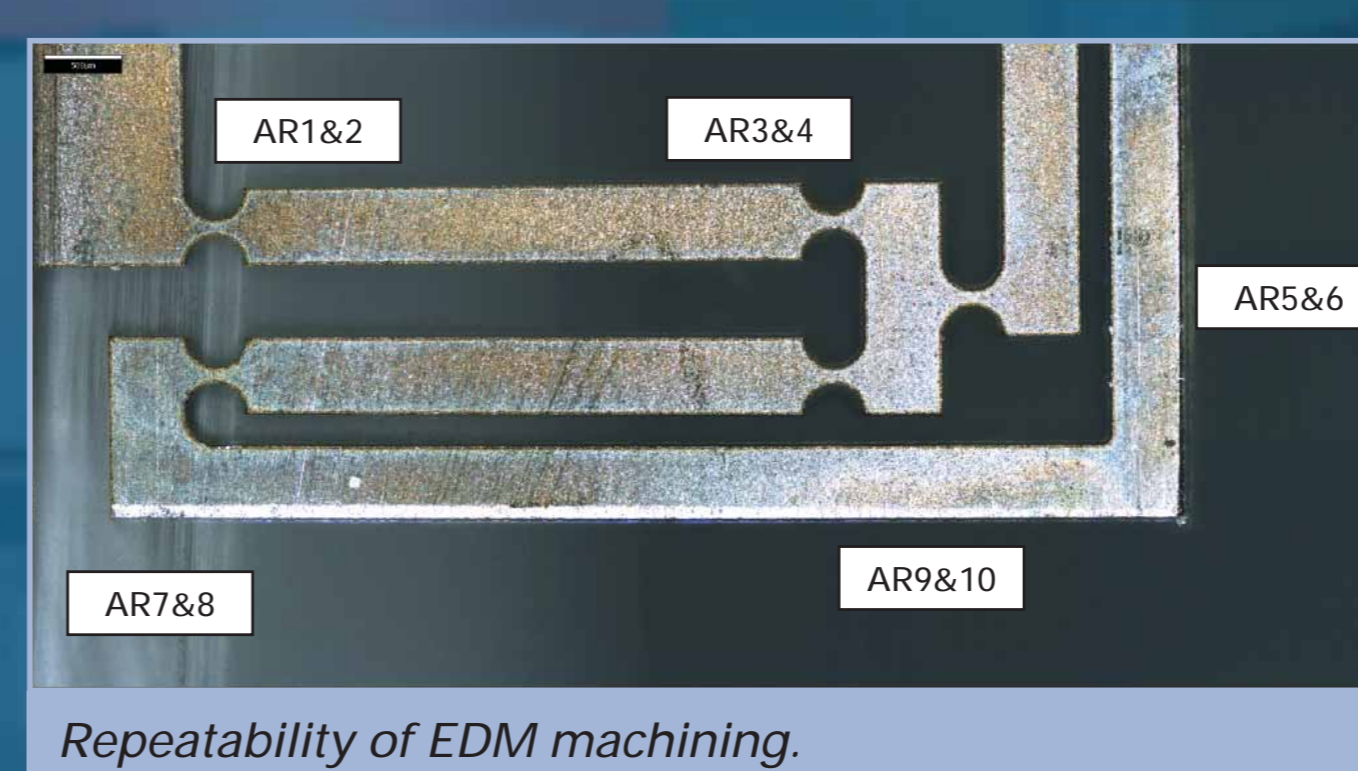
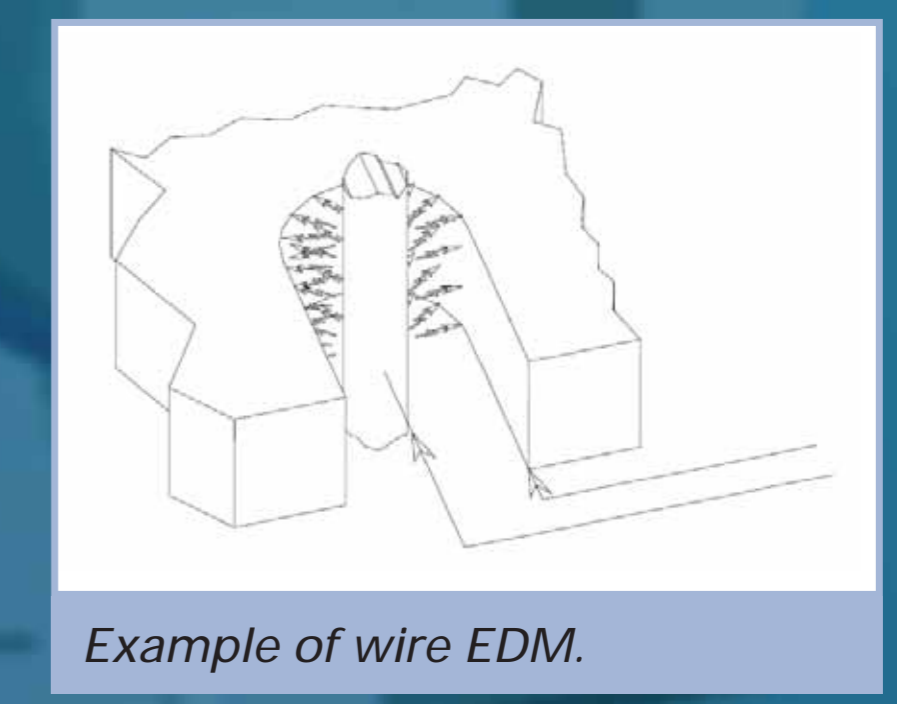
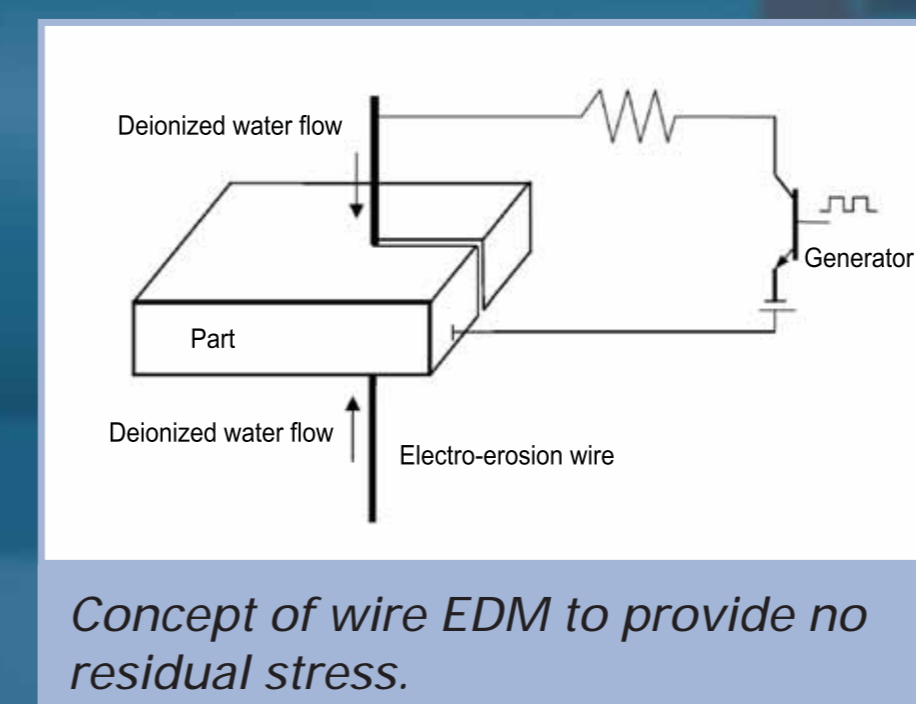
Motors and sensors

- Squiggle motors displacement resolution of 1nm over 1 μm range & 20nm over 5mm.
- Eddy current sensors achieve the no lead wire requisite.

Building

- All components made by EDM, no residual stress added.
- All made in Invar 36 (CTE < 1.3 e-6) this avoids temperature induced errors

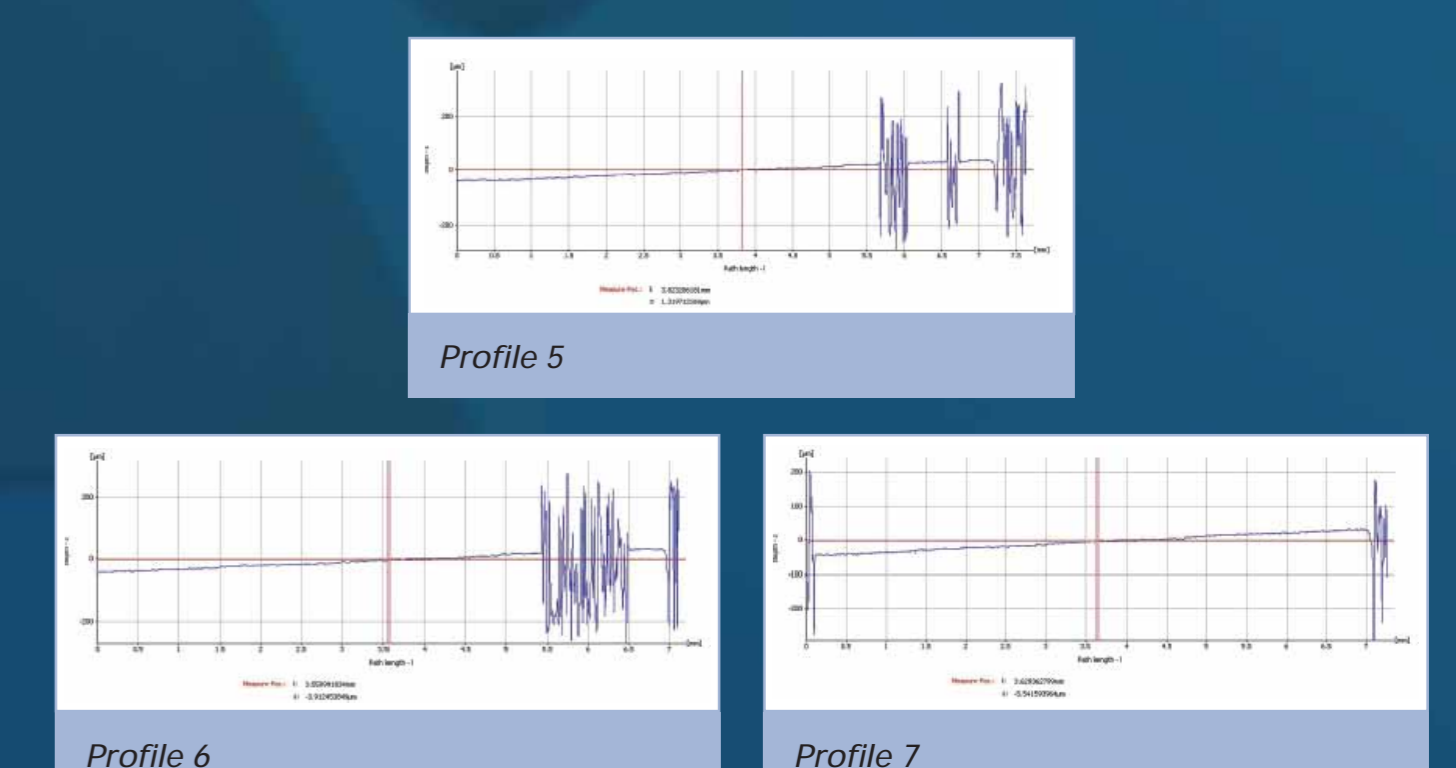
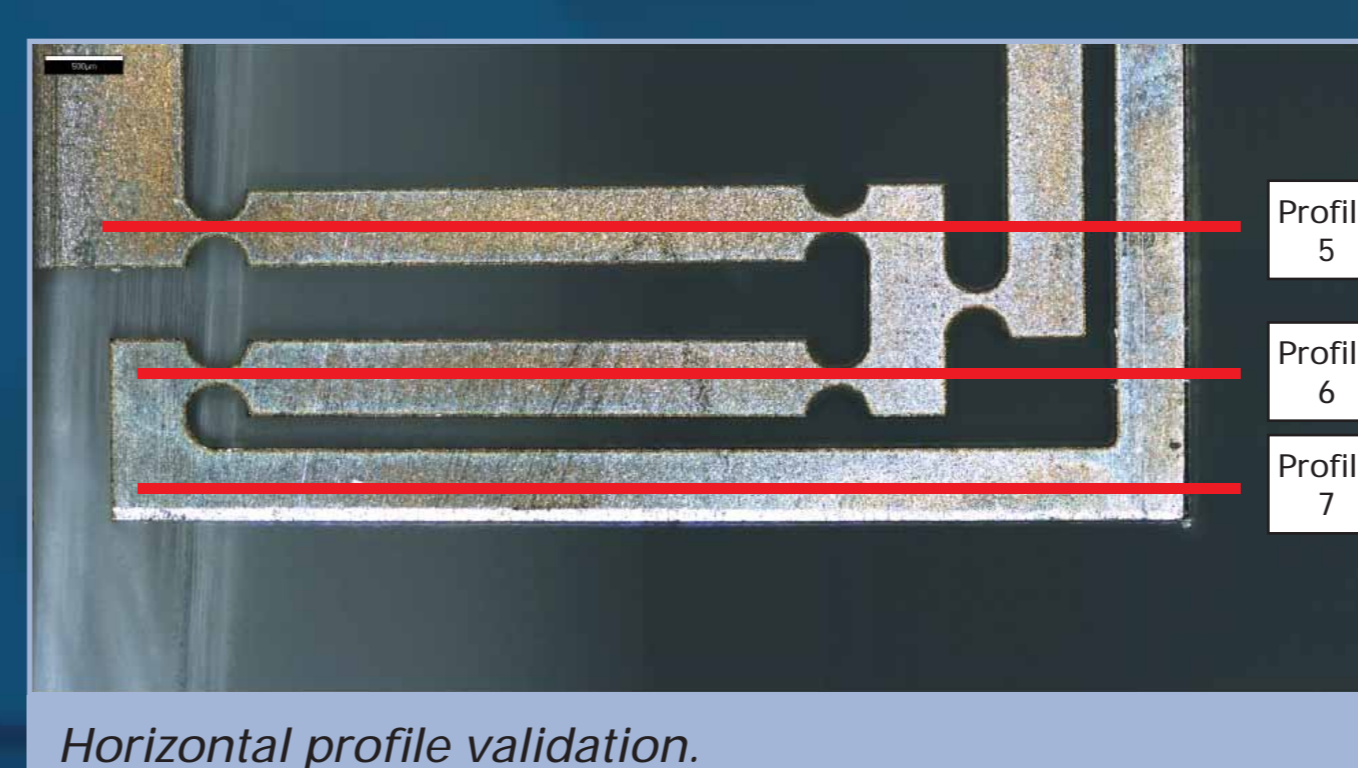
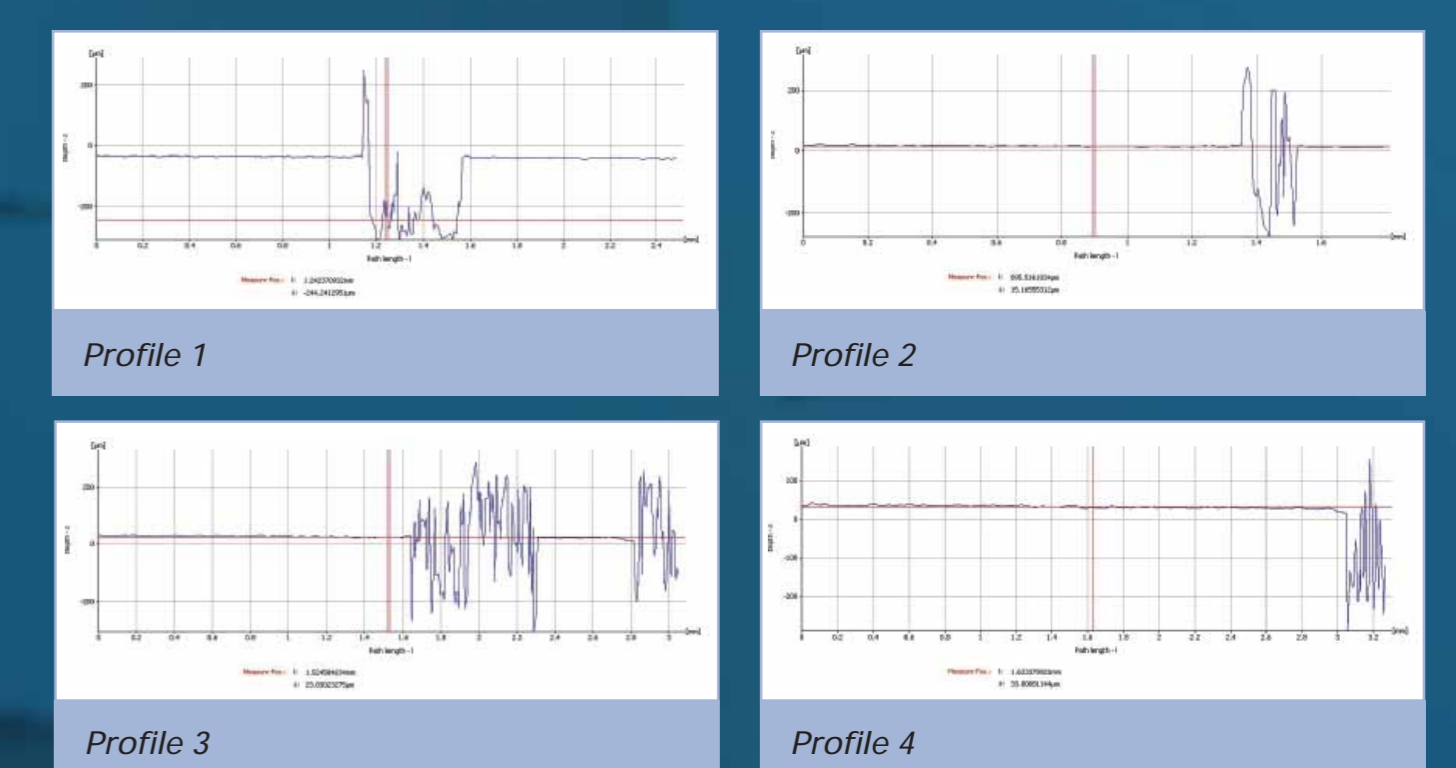
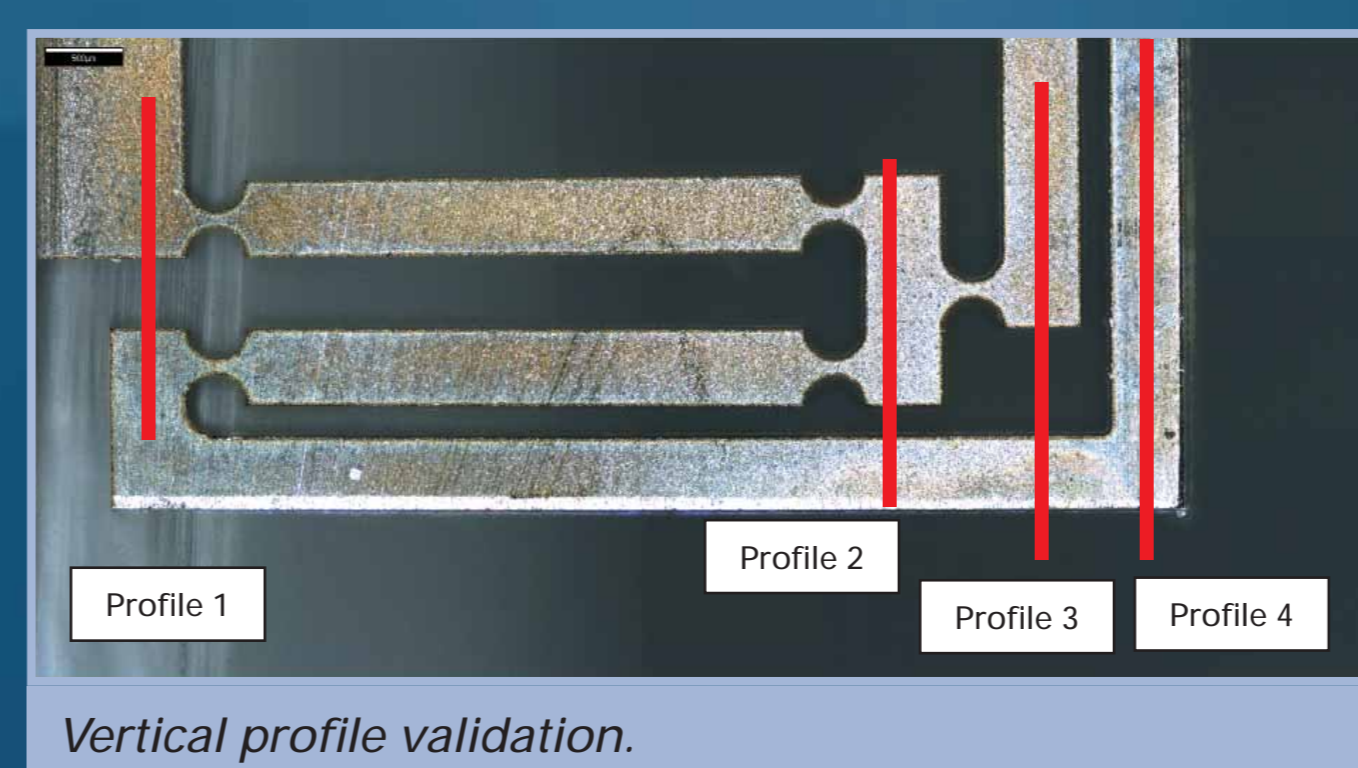
The profiles show that microwire EDM is more than capable of precise cuts to the nearest 3 microns.



r [μm]	length [μm]
AR1	206.1173
AR2	203.6496
AR3	210.225
AR4	205.2474
AR5	207.0039
AR6	206.051
AR7	210.3076
AR8	206.4671
AR9	205.0295
AR10	207.0097
Mean	206.9608
Std. Dev.	2.119628
Min	203.6496
Max	210.3076
Sum	2069.608
MeanSp	206.7355
Robust	205.8238
Count	10

r [μm]	length [μm]
L1	88.18623
L2	85.753
L3	81.9304
L4	87.38466
L5	91.75551
Mean	87.00199
Std. Dev.	3.585579
Min	81.9304
Max	91.75551
Sum	435.0099
MeanSp	87.38466
Robust	87.78544
Count	5

Repeatability of spark eroding the flexure hinges.



Acknowledgements:

The authors wish to acknowledge the support of the UK's Department of Trade and Industry, Geoff Fry from MML manufacturing in Horsham, Dr Roger Morell, Dr Mark Gee, Eric Bennett, Andrew Murray from University of Manchester, Dr Louise Brown, Gerald Smith.