1.1 Possible routes for traceability of strain measurement.

Strain is related to deformation. Therefore, in order to realize a strain reference material, an instrument must be devised to deform a piece of material in a reproducible manner by applying a load. Any effect that causes a material deformation can be envisaged to provide a viable route for traceability. And because strain is a derived quantity, it must be connected to the value of load control by a simple mathematical relation, as exemplified by the accepted method for traceability of strain values in tensile testing. Here, strain is approximated by the average unit elongation in the direction of measurement, determined from total elongation ΔL of a selected gauge length L_0 by

$$\varepsilon = \frac{\Delta L}{L_0} \tag{a}$$

In this simple one-dimensional, two-point case traceability is established by calibrating the devices for measuring elongation (e.g. extensometer calibration rig) and for measuring gauge length against a reference standard for the unit of length such as a laser interferometer or a gauge block, respectively. Mechanical deformation and tracing back strain measurement values to a length standard by using traceable gauge length and displacement values seems a natural choice.

However, less obvious traceability chains can be devised. Electrostrictive materials could be used to trace back strain values to the Volt using the voltage-strain relation; thermal expansion of a calibration body would allow tracing back strain values to the temperature scale. Table 1 compiles possible routes for traceability of strain values and indicates a simplified version of the mathematical description of the effect.

Table 1: Possible routes for traceability of strain values

Primary standard	Possible realizations, generation of strain field	Relevant equation
voltage	generate a strain field by electric field controlled deformation of an electrostrictive or piezoelectric material	$\varepsilon = Q \cdot E^2$
current	generate a strain field by current controlled magnetic field induced deformation of a magnetostrictive material	$\varepsilon = L \cdot H$
temperature	generate an in-plane displacement field by temperature controlled expansion of a body with linear CTE.	$\varepsilon = \alpha_{CTE} \cdot T$
angle	generate a strain field by angle controlled deformation of an elastic material (torsion rod).	$\varepsilon = \kappa \cdot \alpha$
length	generate a strain field by displacement controlled deformation of an elastic material (bending beam, tensile test specimen).	$\varepsilon = \kappa \cdot d$

1.2 Traceability to the unit of length

An important issue is acceptance of the traceability procedure. Traceability cannot just be claimed by a party; it must be accepted, either by virtue of the fact that an accepted standard agency sustains the calibration chain, or that the technique is accepted as traceable by virtue of its principle of operation. Accordingly, hooking strain values to the traceability chain of dimension would have a high acceptance.

The result of a query suggests that traceability to the unit of length is advisable and most likely to be accepted by the experimental mechanics community. This is both because strain is by definition intimately related to length (deformation) and because users are well-experienced in length- and deformation measurement. As soon as traceability is established SPOTS RM can be certified. An uncertainty budget relaxes the need of having the highest accuracy such as in a primary standard.

Mechanical deformation is favoured over thermal or electrical deformation as it allows to directly relate deformation to the length scale. The introduction of deformation is displacement controlled in order not to be influenced by force measurement. The PRM thus fulfills the requirement to "*reproduce, in a permanent manner during its use, one or more values of strain*". In addition, traceability to length is a natural choice for optical techniques that measure displacement from which strain is deduced.