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# Towards an Expression of Uncertainty in Accelerator Alignment

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When we are asked to align something in an accelerator, on a beamline or in a detector, there is always a desired tolerance associated with the alignment. Generally, this tolerance describes how well the something, for example a quadrupole magnet, should be aligned with respect to something else, for example, the adjacent quadrupole magnet.

The problem is that often the person giving the alignment tolerance isn't talking about the same things as the person who is receiving the tolerance information and expected to do the alignment. This can lead to misunderstandings. The problem of speaking a common language to define tolerances so there is no ambiguity in how they are interpreted is addressed by Geometrical Product Specification (GPS), for example ISO 14638:2015.

Once tolerances are explicitly defined, the object can be measured and compared to the theoretical design tolerances. When we have several objects, like magnets on girders, or if we manipulate an object like a magnet several times, we will get several independent comparisons to the theoretical design tolerances. Ultimately, we will be confronted with how to determine how well the tolerances are respected using several independent measurement results.

This is done using the estimation of uncertainty in measurement. This paper outlines a proposal for how to establish a statement of alignment uncertainty following rules outlined in the Guide to Uncertainty in Measurement (the GUM). The GUM and its supplements published by the Joint Committee for Guides in Metrology are generally accepted as providing best practice for the establishment of a statement of uncertainty in measurement.

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