# DEFINITIONS FOR QUANTIFYING PRECISION MECHANICS

Here is a short definition of the terms used in quantifying mechanical systems. They are listed in order of how expensive each is to achieve.

Theoretical Resolution -
This is the calculated smallest move a system can make. For instance, if you have a 4000-count rotary encoder on a 5 mm/rev ballscrew, then you could divide 5 mm by 4000 counts to get a theoretical resolution of 1.3 microns. But this is only theoretical. You may or may not actually be able to make that small of a move due to the difference between static and dynamic friction.

Actual Resolution -
The smallest actual move that could be made, taking into account friction and pre-load. With low-friction mechanics such as air-bearings, cross-roller bearings, ball bearings, but more importantly, linear motors rather that ballscrews, this number can be quite small, but rarely reaches the theoretical number.

Uni-directional Repeatability (Precision) -
The ability of a system to go to the same spot over and over from a single direction. Lets say in the above mechanical system you command the system to go to a position, from zero, of 100 mm. It calculates the number of encoder counts and goes that number of encoder counts. In this case since it travel 5 mm/rev, you need to command 20 revs x 4000 counts, or 80,000 counts. But this term is not too concerned with where you landed the first time. If you marked that first landing spot, go back to zero, then back to 100 mm, and measured how close you came to the first spot, that would be the uni-directional repeatability. Statistically, to get an actual spec, you need to tell the system to go to lots of different spots lots of times, and then do a statistical analysis of those results, and different manufacturers do this analysis differently to be able to publish good-looking values.

Bi-directional Repeatability -
Same as above, except you must run the test approaching the commanded spot from both directions.

Accuracy -
There are a few specific types, and they interact with each other, but they all have two common aspects. 1) Accuracy defines how close you came to your desired target the first time. 2) Accuracy is almost always based on the mechanical part in the system.

Positional Accuracy -
If you tell the system to move to position 100mm, positional accuracy defines how close it comes to 100mm along the axis of travel. (for instance, 100mm +/- 4 microns). It is necessary to also define the distance over which this is measured, for instance, +/- 2 microns per 50 mm. One other often overlooked thing - your positional accuracy is only as good as the repeatability of your starting position!

Straightness/Flatness -
This begins to measure where you landed in 3-d space, rather than just along one axis. The further the load is from the center of axis of travel the more this has an impact on positional accuracy. To actually do the calculations, you must know the angular errors of the stage over its complete travel distance (non-trivial). Those angular errors also affect the repeatability of the stage. This is the most expensive specification to obtain.

Nick Repanich
Adj. Research Professor
California State University - Chico