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Tool Probe Mounting System Explained

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Tool Probe Mount
Main Components

Kinematic Top
Steel Hex with 3 pressed in bearing balls and 3 magnets.

Kinematic Base
Steel Hex with 6 pressed in dowel pins.

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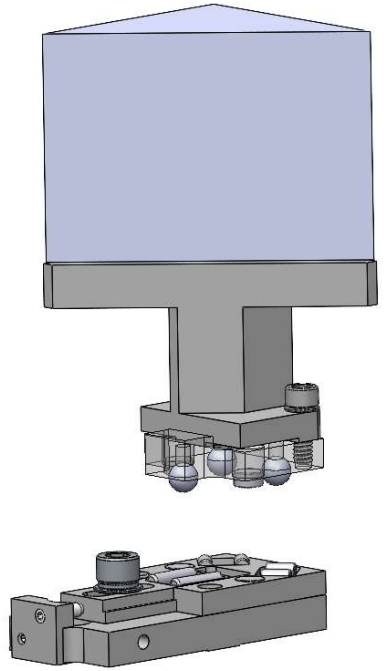
How does this system work? Kinematic Mount

The tool probe mount is a “kinematic” mount. Kinematic mounts have a long and proven history for repeatable mounting and demounting of precision components such as for precision optics.

We adapted a kinematic mount for rapid, tool-less repeatable mounting and demounting of CNC machine tool probes. Then we patented it.

On the left is commercially available kinematic mount from Thorlabs for mounting and demounting commercial optics/components. Notice 3 balls, 6 pins and disc magnets.

On the right is a custom designed kinematic mount for mounting and demounting a custom optic. Again, 3 balls, 6 pins and magnets.



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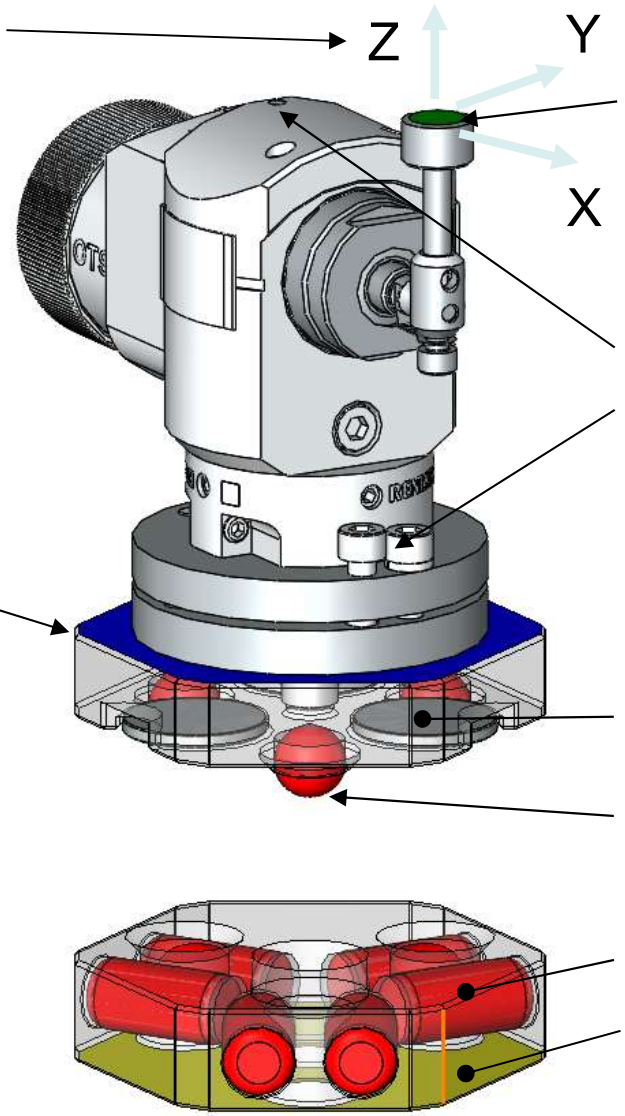
How does this system work? First, Some Nomenclature…



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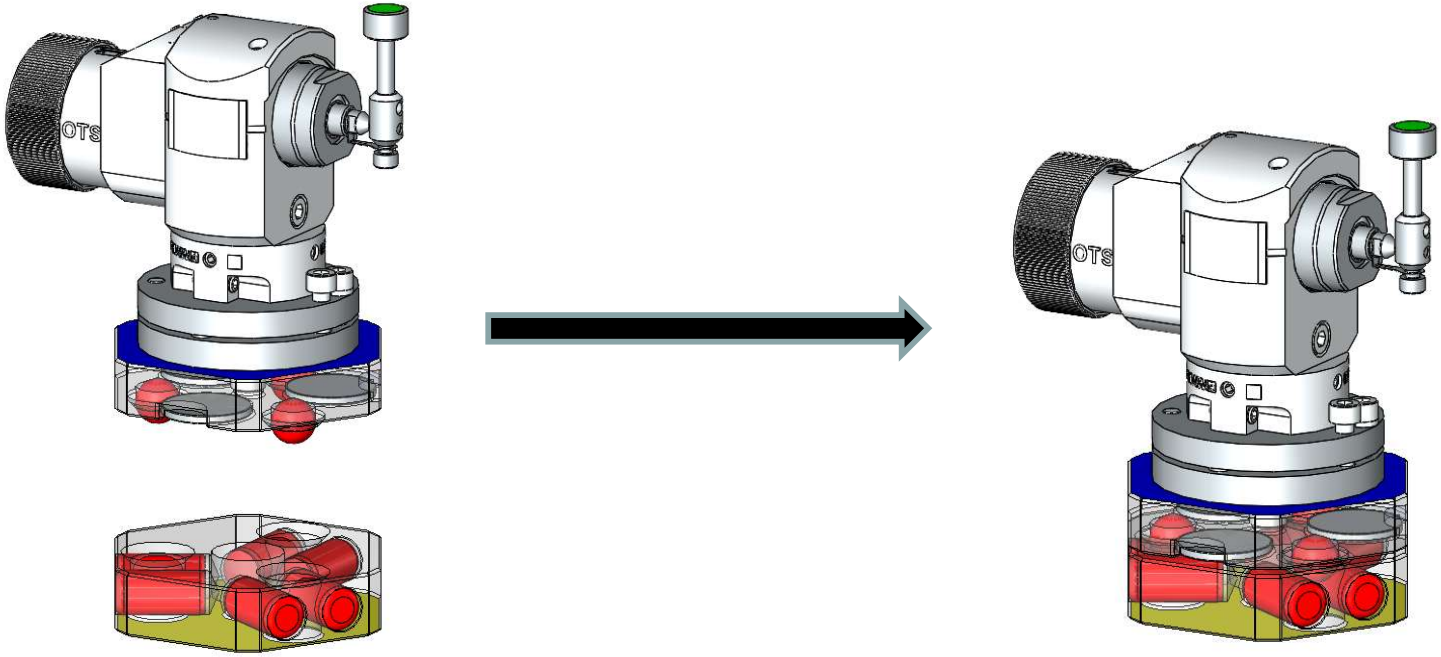
How does this system work? Kinematic Constraint

The principle behind the repeatability of the kinematic mount require that all 6 degrees of freedom (DOF) of a rigid body (3 translations and 3 rotations) must be removed, correctly.

There exist a number of kinematic mount designs that correctly remove all 6 DOFS, however in our design, we use what's known as a Maxwell coupling i.e. a “3 Ball, 3 Vee” design. Here, we use a pair of pins is to simulate a “Vee” which is standard practice. By arranging the 3 balls and Vee’s symmetrically as shown, kinematic constraint is achieved ensuring mounting repeatability to a few microns.



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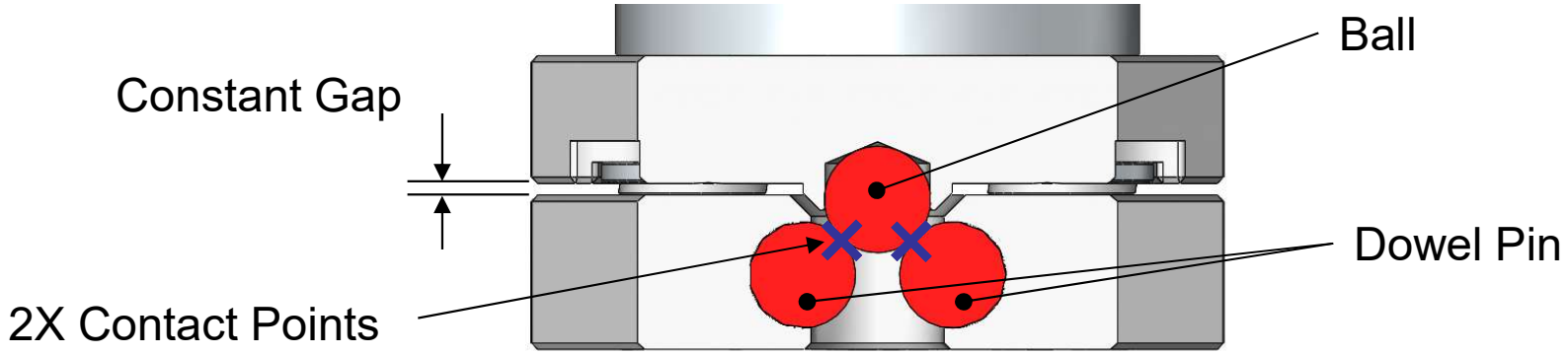
How does this system work? Removing Degrees of Freedom

How does the system remove all degrees of freedom? Looking at a single ball and pin pair (vee) when nested, two contact points are created. Due to the 3 ball & 3 Vee spatial arrangement of, exactly 2 degrees of freedom of the system are removed. This is repeated for the other 2 ball/vee interfaces and when all are seated, exactly 6 DOFs are removed. This completes the structural coupling between the Kinematic Top and Kinematic Base. No other surfaces are contacting.

Note that when mated, there is **a constant gap between the Kinematic Top Hex and Kinematic Base Hex**. These components never come in contact, by design. If they did, the balls and pins would not seat properly and repeatability would be negated. Be sure to keep this gap free of debris when mating components.



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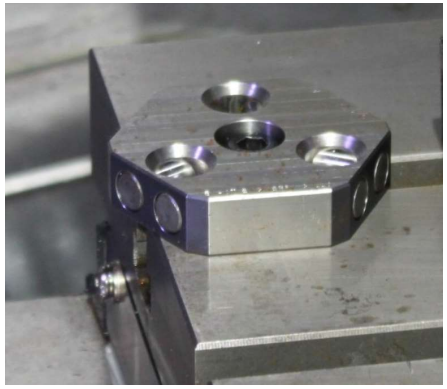
Installation

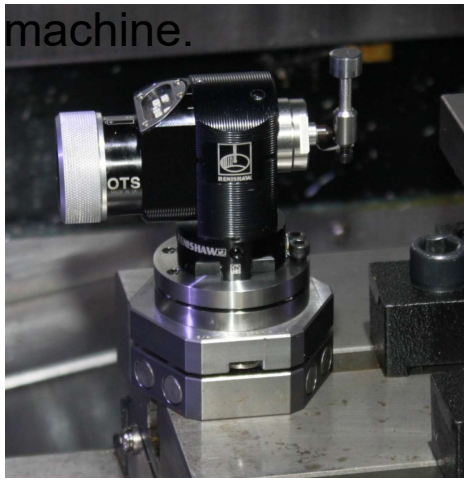
Installation of the Tool Probe Mounting System is similar to normal procedure with a few extra steps…

Install a Kinematic Base onto machine. Typical t-slot install shown below.



Install tool probe onto Kinematic Top, then install magnets.

Install tool probe w/Kinematic Top onto Kinematic Base in machine.



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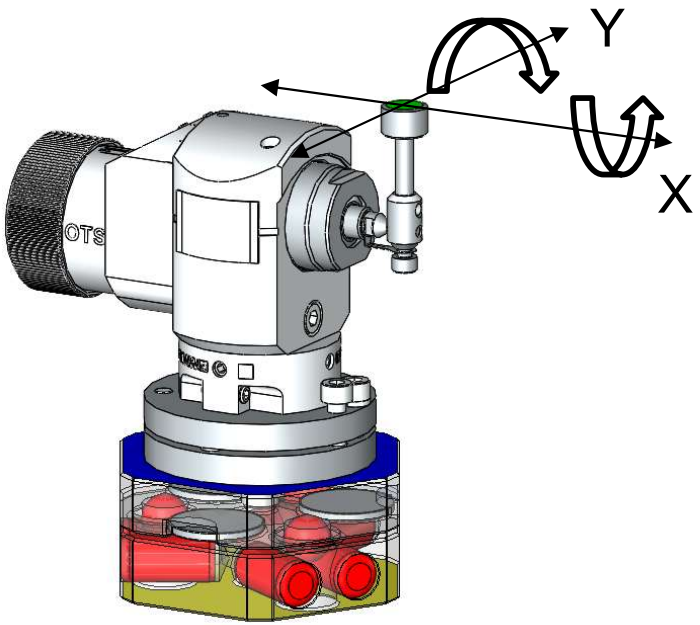
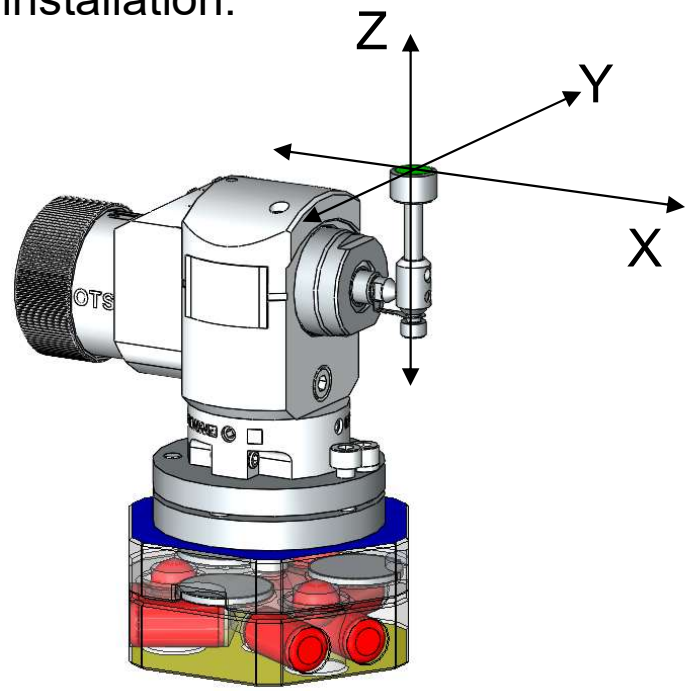
Alignment & Calibration

With the system installed in the machine…

Alignment
Per normal procedure align tool probe surface to machine XY axis using tool probe X-rotation, Y-rotation and a test indicator. This tool probe is now considered “Aligned”



Calibrate
Per normal procedure, calibrate the X,Y center and Z height of the tool probe button. This completes installation.



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Probe Sharing
Multiple Machine Installation

For sharing a tool probe with another machine, an additional Kinematic Base is needed and can be purchased on our website. Below are instructions for multiple probe sharing installation.

1. Install a Kinematic Base on Machine 2.
2. Install a previously “Aligned” tool probe from another machine onto Machine 2 Kinematic Base.
3. Confirm the probe surface is parallel to Machine 2 XY axis’ using a test indicator.
4. Calibrate XY center and Z height of tool probe in machine 2 per normal procedure.

Now you can swap between machines without any further alignments or calibration.

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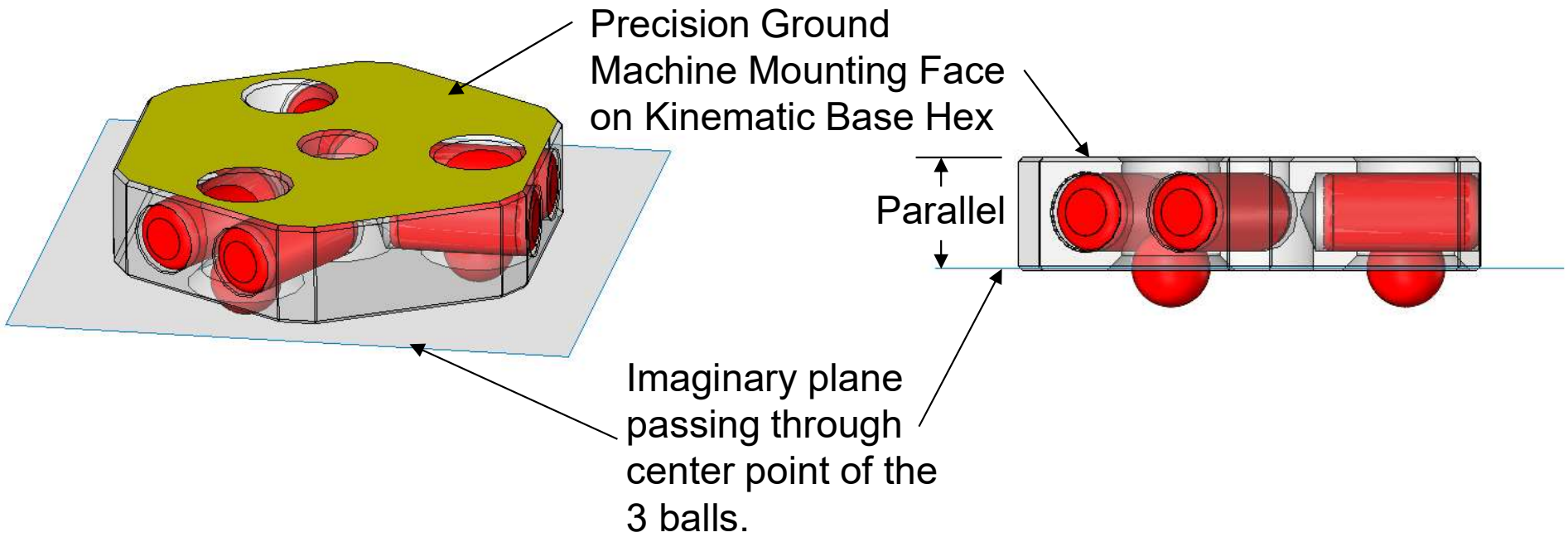
Probe Sharing
How is this Possible?

When we manufacture the kinematic bases, we grind the machine tool mounting interface (yellow surface below) on each Kinematic Base to be parallel to a plane established by the center point of each ball when mated to the pins. This step ensures the parallelism of each base is identical. Note the height of this yellow face plane does not need to be match controlled as it is calibrated out during installation, same as the as the XY center of the probe, which is unique to each machine install. No other surfaces need to be precision machined as they are not functional surfaces.



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Additional Notes

- All the repeatability magic happens between the contacts of the precision balls and precision pins. We use these low-cost components because they are hardened, readily available and of high precision and surface quality.
- Mating the 3 balls onto the 6 pins cannot be done incorrectly, requires no tools or special skills and will always repeat location.
- Tool-less mounting and demounting is provided by the magnets which ensure symmetrical and repeatable nesting forces of the balls onto their dowel pins. The magnets also ensure that the system remains coupled during use.
- Due to the magnets, tool probe breakaway from the Kinematic Base is possible in the event of a crash. This can reduce or eliminate tool and or tool probe damage. For example, yours truly once entered a tool length that was too short when probing a tool. Before the machine could stop on its own, it drove the tool through the probe button and tipped the tool probe off the Kinematic Base. No damage occurred to the tool or the tool probe.

Any Questions? Call or email us directly: 781-431-7663, david@exactengineering.net

No other surfaces need to be precision machined as they are not functional surfaces.