

## Application Note 1

# Machine Tool Alignment

## Boring Mills, Gantries, Machining Centers, VTLs

### System Recommendations

### L-743 Machine Tool Alignment System



Whether it's machining centers, boring mills, lathes or grinders, Hamar Laser has an alignment system to fit your geometric calibration needs. All Hamar Laser alignment systems use patented, state-of-the-art technology to align your metal cutting machinery as quickly and simply as possible. In almost all cases, the alignment process can be completed 60 - 70% faster than using conventional means (levels, squares, indicators, straight edges, etc.) or interferometry (linear measuring lasers).

### Traditional Methods Too Time Consuming

Traditional alignment methods usually require days or even weeks to align a machine tool. That, combined with stack-up errors that can limit the machine's tolerance potential, makes aligning a machine tool to today's ever-tightening tolerances a very time-consuming and difficult exercise. In fact, most companies rarely check alignment of their machines because it takes too much production time.

Hamar Laser's alignment systems allow you the time to align your machines *and* keep pace with production. With accuracies

down to  $\frac{1}{4}$  arc second (0.000015"/ft or 0.001 mm/M), Hamar Laser's alignment systems will also help your machines cut better parts, reduce scrap rates and increase productivity.

### Alignment First, Linear Positioning Second

One of the biggest misconceptions in the machine tool industry is that proper linear positioning is all that is needed to make quality parts. Our customers have found out the hard way that making quality parts requires checking and calibrating the machine's geometry (flatness, straightness, squareness and parallelism) *first*. Only then should the linear positioning of a machine tool be checked and calibrated. Failing to follow this sequence will result in a costly trial and error period, poor part quality and reduced throughput.

### Two Types of Machine Tool Lasers

Our lasers systems are available in two types:

- *Straight-Line Laser Systems* - designed for lathe, turning center, bore and cylindrical grinding applications.
- *Multi-Plane, Continuously Rotating Laser Systems* - designed for machining center, vertical turning lathe, boring mill and surface grinding applications.

### Two Levels of Accuracy

Our continuously rotating laser systems are available in two accuracy grades: the L-730 Precision Series and the L-740 Ultra-Precision Series. Each series offers several different laser systems with single, dual and triple-plane versions. The L-730 Series is designed for those with accuracy needs of 0.00012"/ft (0.01 mm/M) or higher and the L-740 Series is for those with accuracy needs of 0.00002"/ft (0.0017 mm/M) or higher.



5 Ye Olde Road, Danbury, CT 06810 • Phone: (800) 826-6185 • Fax: (203) 730-4611  
E-mail: [sales@hamarlaser.com](mailto:sales@hamarlaser.com) • Internet: <http://www.hamarlaser.com>

## The L-743 Machining Center Alignment System

The L-743 Ultra-Precision Triple Scan® Laser is an ideal instrument to quickly and accurately calibrate the geometry of almost all machining centers. It is the only laser in the world to offer three automatically rotating laser planes that are accurate enough for today's ever-tightening tolerances. This creates a powerful tool that not only FINDS, but also FIXES geometry problems, all in a fraction of the time needed with conventional methods.

### Align 70% Faster Than Other Methods

Continuously sweeping lasers and live data output create a powerful combination to align machining centers up to 70% faster than traditional or interferometer methods. Downed machines will be up and running, producing quality parts in record time. HLI's continuously sweeping lasers are far superior to other point-and-shoot laser systems that require time-consuming manual laser rotation and target setup for each point measured. They also allow the use of multiple targets, which is especially helpful for large machine tools.

### Simultaneously Measure 3 Axes with One Setup

Another great time saver is the L-743's ability to measure the three main axes of a machine at the same time. Not only can you measure the flatness and straightness of each axis, but you can also measure the squareness of the three axes. And if there are any additional axes, such as a rotary table or extending quill, you can easily check the parallelism to the main machine axes with the same setup.

### Reduces Machine Downtime and Part Setup Time

By providing live alignment data, misalignment errors can be quickly and easily fixed without having to change the setup. This is a tremendous benefit, especially if you are used to using an interferometer or autocollimator, where the entire length of an axis must be measured before the straightness or flatness can be determined and the data provided is not even live.

### Reduces Stack-Up Errors

A major problem with aligning machine tools using conventional methods is that many different alignment tools must be used, requiring a lot of time and increased stack-up errors. An alignment is only as good as the tools used to perform it. The machinist level, for example, has a resolution of .0005" per foot, which is not very accurate for today's ever-tightening tolerances. The L-743's laser planes, by contrast, have a flatness of ½ arc second (0.00003"/ft or 0.0025 mm/M) in a 180° sweep and ¼ arc second (0.000015"/ft or 0.001 mm/M) in 90° sweep.

### Squareness Made Easy

In addition, the L-743's three laser planes are square to each other up to 1 arc second (0.00006"/ft or 0.005 mm/M), providing a single reference from which to measure machine geometry. If you have ever tried to set up an interferometer to check squareness, you will be amazed at how quickly and easily the squareness of not just one axis, but *all* axes can be measured, usually with one setup. Where an interferometer may take hours just to set up a squareness check, the L-743 takes 15-25 minutes. And, unlike a cylindrical square, the L-743 can check the entire length of a machine's axis, up to 100 feet (30.5 meters), not just 12" (305 mm) or 24" (610 mm) of it.

### Recommended System Configuration

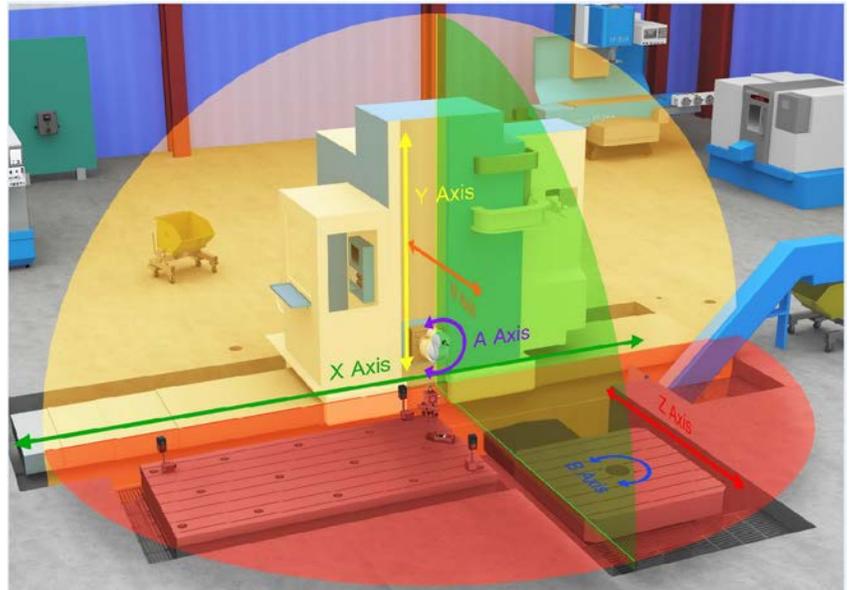
L-743 Ultra Precision Triple Scan Laser  
(3) A-1519-2.4ZB Single-Axis Wireless Targets  
R-1355-2.4ZB PDA Display w/Read9 Software  
A-910-2.4ZB Computer Radio Interface  
S-1387 Machine Tool Alignment Software for Windows  
L-106 Instrument Stand  
A-809XL Shipping Case

### Computer Accessories

R-342 Notebook Computer  
R-1342 Toughbook Laptop  
S-1388 Plane5 Software

### Optional Accessories

A-1520-2.4ZB Single-Axis Wireless Scan Target

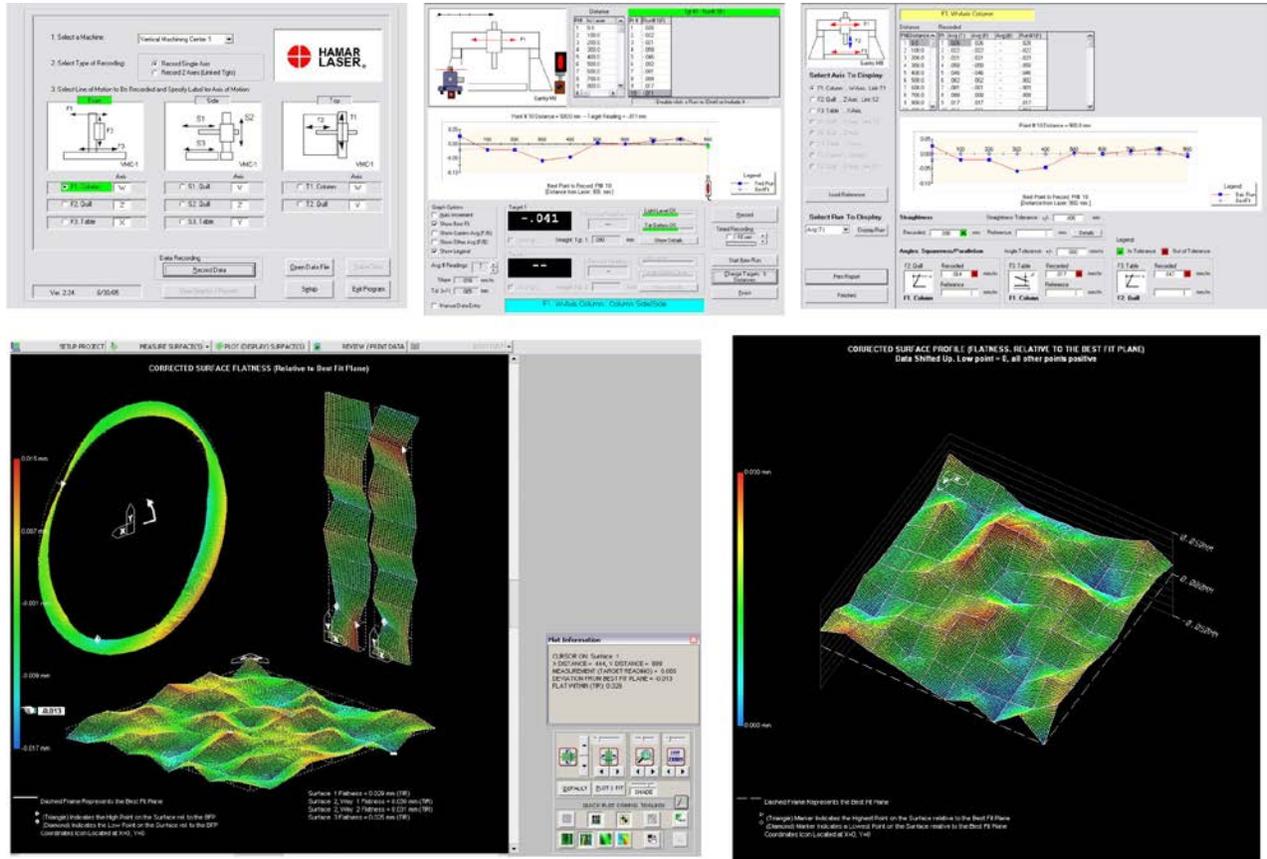


## Wireless Targets and Readout Speed Setup

With Hamar's new wireless targets (A-1519-2.4ZB) there is no need to string long extension cords to reference targets. The targets have a measuring range of  $\pm .5"$  (12.7 mm), a resolution as low as 0.00002" (0.00058 mm) and can be used up to 100 feet (30.5 meters) from the laser. The R-1355-2.4ZB Readout uses a PDA, color software and a wireless receiver to display up to 8 targets simultaneously. Other features like electronic zeroing and target averaging help to speed setup and alignment.

## Software Quickly Collects and Analyzes Machine Tool Geometry Data

Hamar Laser's Machine Tool Geometry Software analyzes lines of motion for a machine tool, similar to the methodology used in ASME's B5.54 Standard. Our Plane5 Software analyzes multiple planes and surface types (squares, rectangles, frames, ways, circles and rings) and presents the analysis in 3D graphics. Both sets of software automatically download alignment data, save data analyses and produce alignment reports that clearly and concisely show the machine's condition (report summary only shown on following page).



Hamar Laser's Machine Tool Geometry Software and Plane5 Software

## Alignment System Features

- 3 continuously rotating laser planes with operational range of 100' (30.5 meters) in radius.
- Laser planes flat to 1/2 arc second (0.00003"/ft or 0.0025 mm/M) in 180° sweep and 1/4 arc second (0.000015"/ft or 0.001 mm/M) in 90° sweep.
- Planes are mutually square up to 1 arc second (0.00006"/ft or 0.005 mm/M).
- Includes L-123 Pitch/Roll/Yaw base with coarse and fine adjustments.
- Standard Targets: A-1519 2.4ZB Wireless Target with  $\pm .5"$  (12.7 mm) Measuring Range and 0.00002" (0.00058 mm) Resolution.
- Backlit levels accurate to 1 arc second (0.00006"/ft or 0.005 mm/M).
- Diode lasers 2 times more stable than HeNe based laser systems.
- Completely self-contained.
- Instant on with virtually no warm-up.
- Typical setup time 20 minutes or less.
- Battery or AC powered.

## How the Alignment System Works

The following section describes how the laser is used to measure straightness, flatness, squareness, levelness and parallelism on a 6-axis horizontal floor mill. Note that if a machine is going to be aligned, rather than just measured, it is important to put the laser on an instrument stand. If the laser is on the machine bed or table, adjustments will likely move the laser and affect the setup.

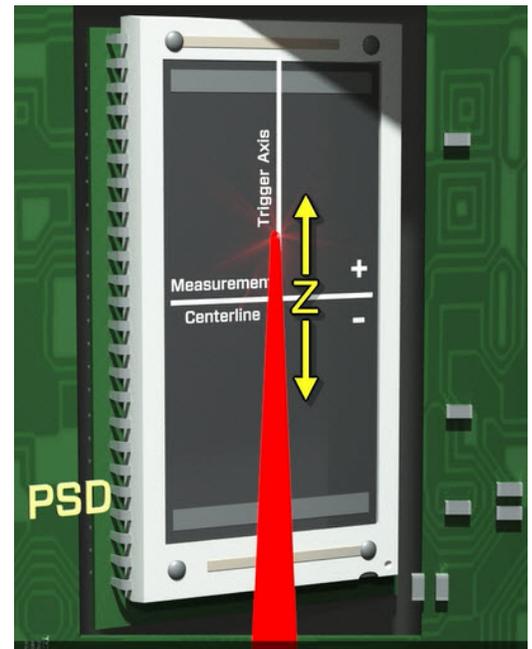
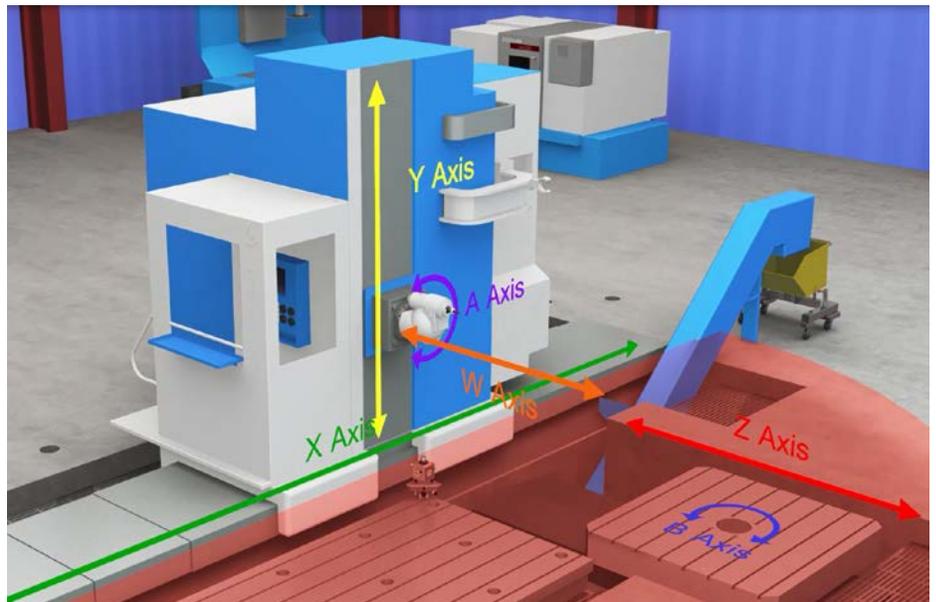
### Setting Up (Bucking-in) the Laser

When setting up the laser to measure either straightness or flatness, you must first position the laser plane(s) so that they are parallel to the reference points on the machine. This process is called "bucking in" the laser. To speed up the setup process, the use of 3 reference targets is highly recommended.

- For measuring straightness, 2 reference points are needed.
- For measuring flatness, 3 reference points are needed.
- For measuring the flatness, straightness and squareness of a machining center, 5 reference points are needed.

In this procedure, we'll use 3 targets for the initial 3-point setup and one target for the 2-point setup.

Once the laser has been set up to its reference points, the targets can be repositioned to measure the various surfaces or lines of motion for deviation from the references. A plus (+) reading indicates a target is higher than the reference points, and a minus (-) reading indicates it is lower.

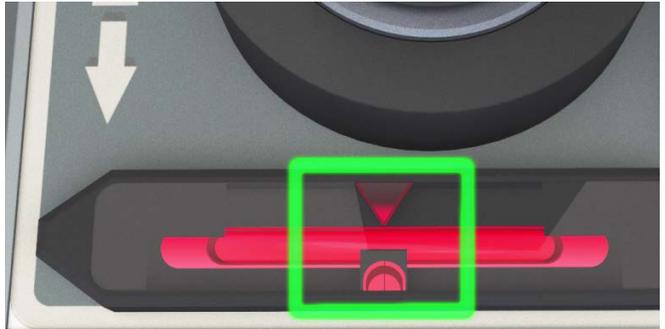


## Procedure

1. Place the laser on the table at a spot that provides the ability to measure all the axes from the same setup.



2. Level the Pitch-Axis level via by using the coarse and fine adjustments to line up the edges of the bubble. Repeat the process with the Roll-Axis level vial. Now the red laser plane is level to earth



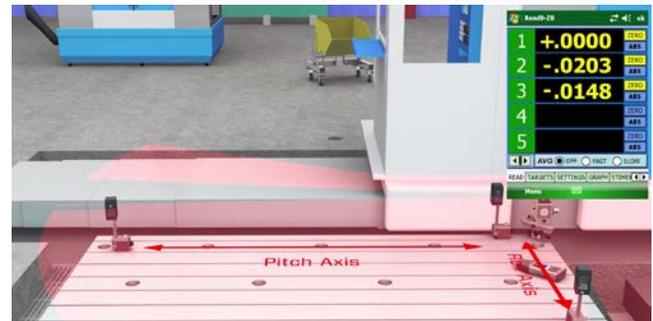
3. Place Target #1 at a location next to the laser and mark the outline of the magnetic base for good repeatability. Point the laser at the target window and adjust the target height until the laser beam is centered.



- Turn on the laser rotation (which also turns on the targets). Target #1 data displays in the Read9 software on the PDA. Zero the display. Remove Target #1 and replace it with Target #2. Zero the Read9 display for Target #2. Repeat the process for Target #3.



- Spread out the targets on the table on three reference points, two along the Pitch Axis and one on the Roll Axis.

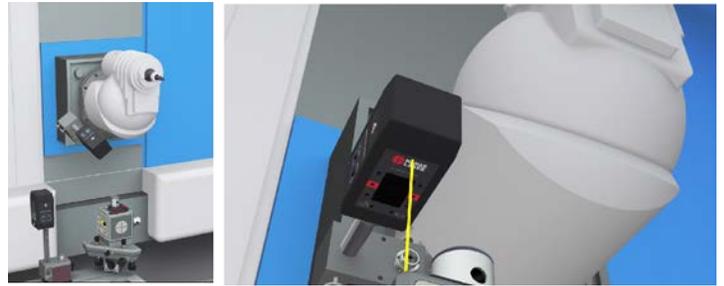


- Looking at the data for Targets #1 and #2, adjust the Pitch-Axis knobs on the laser until the two values are equal. Switch to Targets #1 and #3 and adjust the Roll-Axis knobs on the laser until those two values are equal. Now the target values for all three targets are equal and the laser plane is aligned to the table.

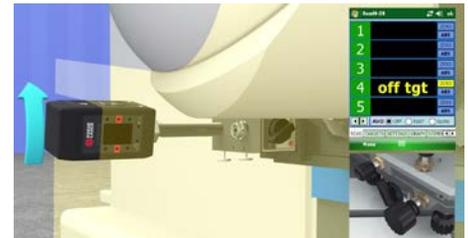


## Aligning the Laser to the X-Axis Travel

1. Mount Target #4 on the ram, move the spindle and adjust the target height.



2. Power on the laser and zero the target in the Read9 PDA. Move the column down to the end of the X-Axis travel and rotate the target head to point towards the laser.



3. Turn the Yaw-Axis adjustment knob to center the laser to zero on the target.



4. Return the column to its starting position and rotate the target toward the laser. Zero the target.



5. Send the column back to the far end of travel and tweak the Yaw-Axis adjustment knob to zero the laser.



6. When the target reads zero at both ends, the laser is aligned to the X-Axis.



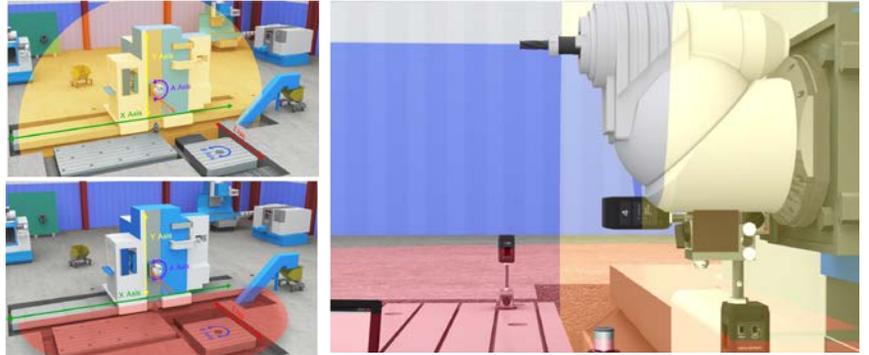
## Measuring X-Axis Straightness and Flatness Simultaneously

The straightness and flatness for X can be measured simultaneously by adding a second measuring target to the bottom of the spindle ram. The targets come with a 3-piece post set, so a shorter post may be used to adjust the target height to pick up the red laser.

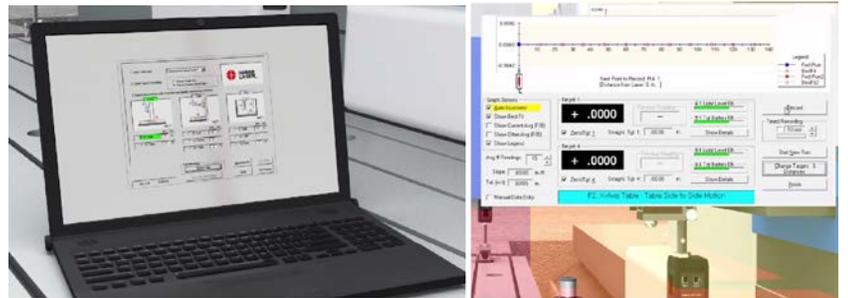
1. Attach a second measuring target to the bottom of the spindle ram with a short post. Adjust the target height to pick up the red laser.



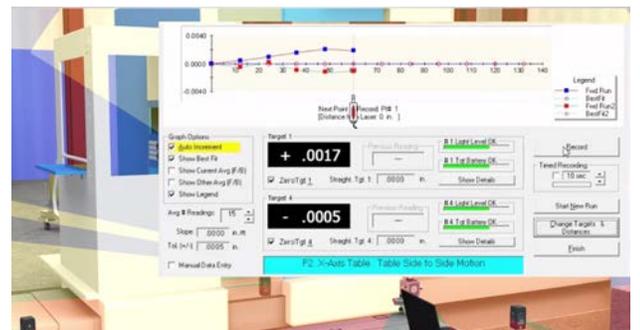
2. Turn on the rotation for both laser planes. The Gold Laser (top left) measures X-Axis Straightness and the Red Laser (bottom left) measures Flatness.



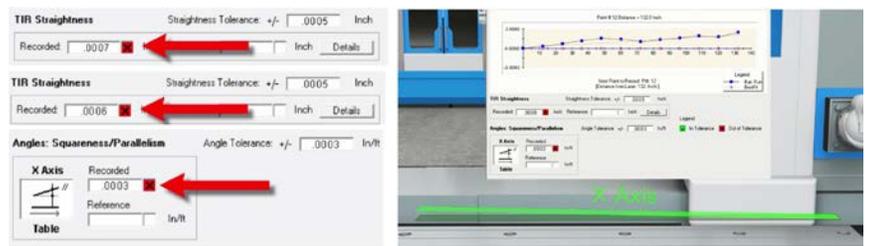
3. The target readings are sent wirelessly to a laptop computer, where our Machine Tool Geometry software records them. Select the axis, enter the length of travel and number of points, and ensure the targets are pointed at the laser. Hit the **RECORD** button and the Machine Tool Geometry software records both targets' data simultaneously and plots out straightness.



4. Continue to move the column to each point and hit Record. After the data has been taken, return the column to the home position.

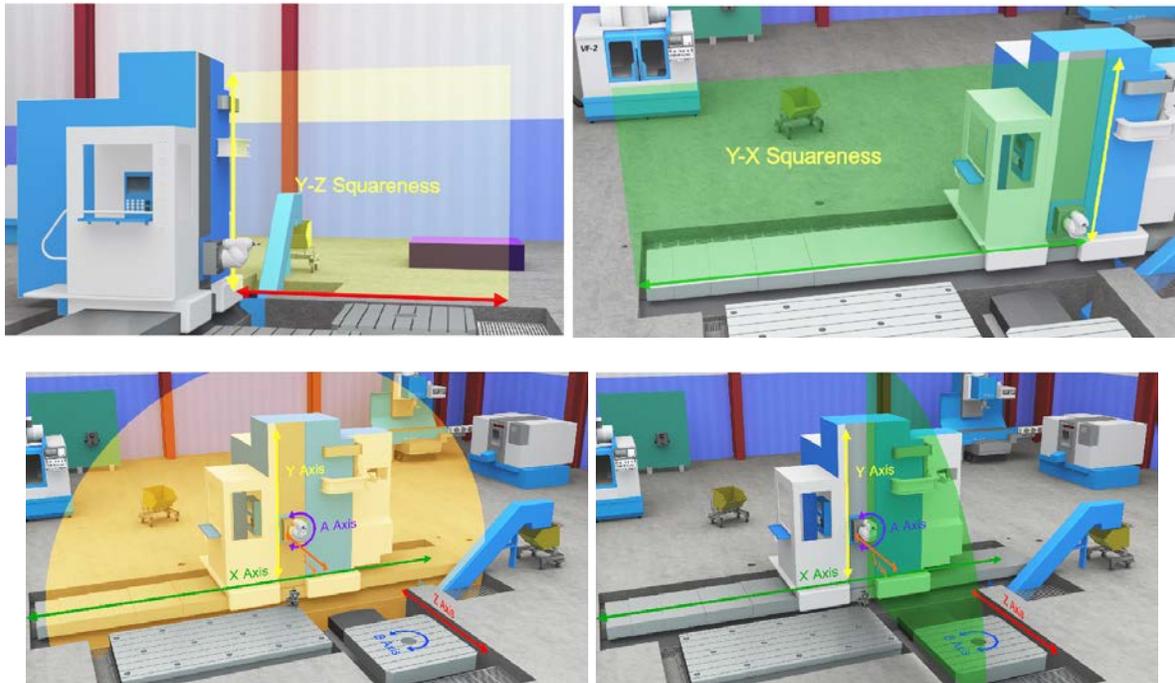


5. The X-Axis results show a Straightness error of .0007" TIR and a Flatness error of .0006" TIR. The slope of the Best Fit line is .0003 in/ft, which means the X-Axis is sloping UP relative to the table.



## Y-Axis Flatness and Straightness and Y-Z / Y-X Squareness

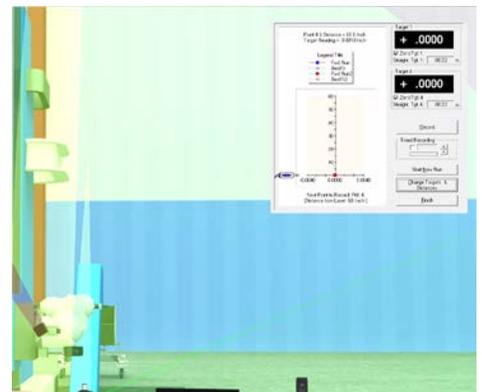
After measuring the Y-Axis flatness and straightness, the Machine Geometry software calculates the Y-Z and Y-X Squareness. The Gold Plane (bottom left) measures Y Flatness and the Green Plane (bottom right) measures Y Straightness.



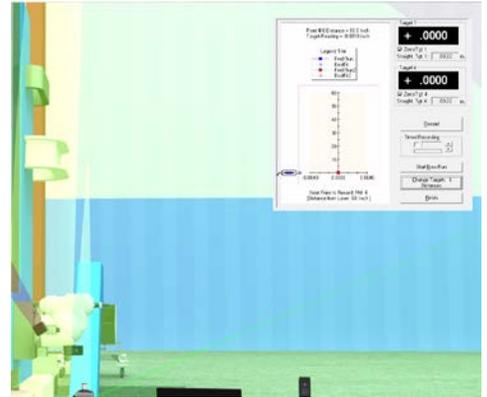
1. To measure the Y-Axis, move the second target to the side of the spindle and adjust the column and target height to center the laser in the window.



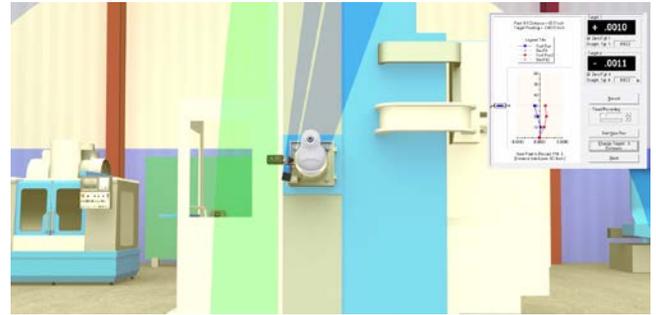
2. Turn on the laser rotation and zero the targets.



3. Move the column, pause a few seconds, and click **Record**. Repeat for each point.



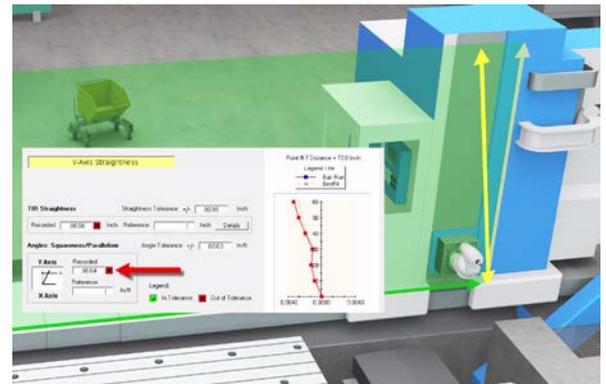
4. The Gold Plane measures the squareness of the Y-Axis to Z and the Green Plane measures Y to X squareness.



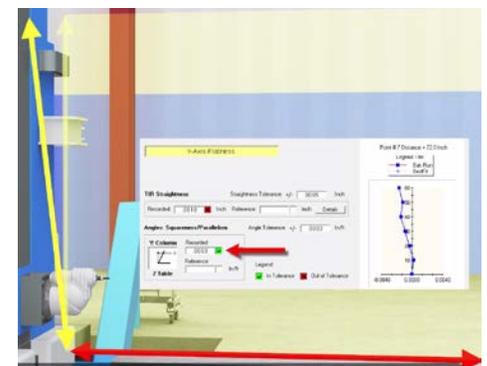
5. As before, the Machine Tool Geometry software does the straightness and squareness calculations. The results show .0010" TIR for flatness and .0008" TIR for straightness.



The X-Y Squareness is .0004 in/ft., meaning the column is leaning to the left.

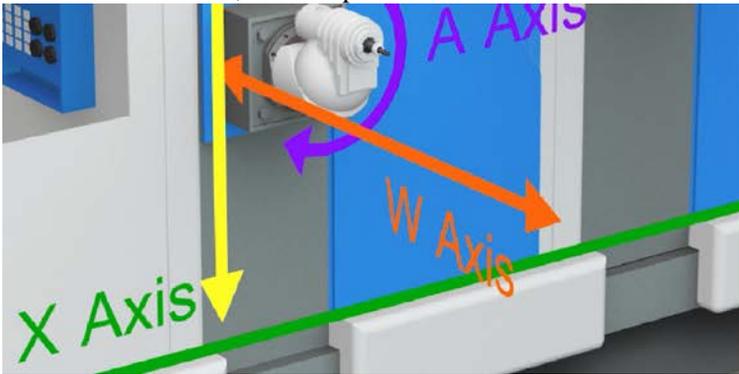


7. The squareness of Y to the tables is .0003 in/ft, meaning the column is leaning back.



**W-Axis Flatness and Straightness, W-Z (in X) Parallelism, W-Z (in Y) Parallelism**

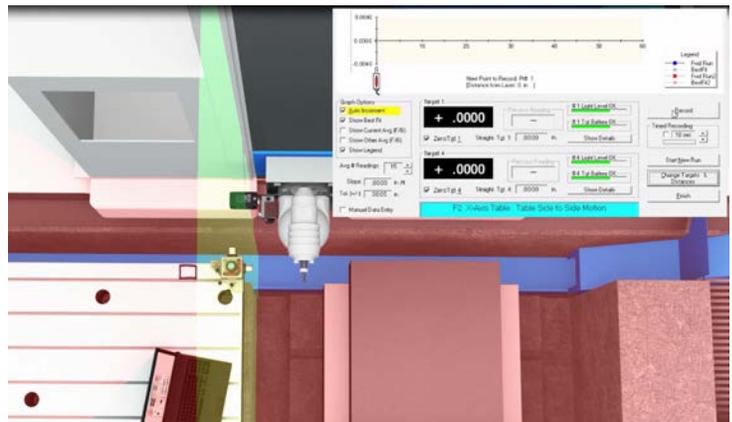
Without changing the L-743 setup, the W-Axis can be measured for flatness and straightness and parallelism to the Z-Axis in the Y direction, and the parallelism to the Z-Axis in the X direction.



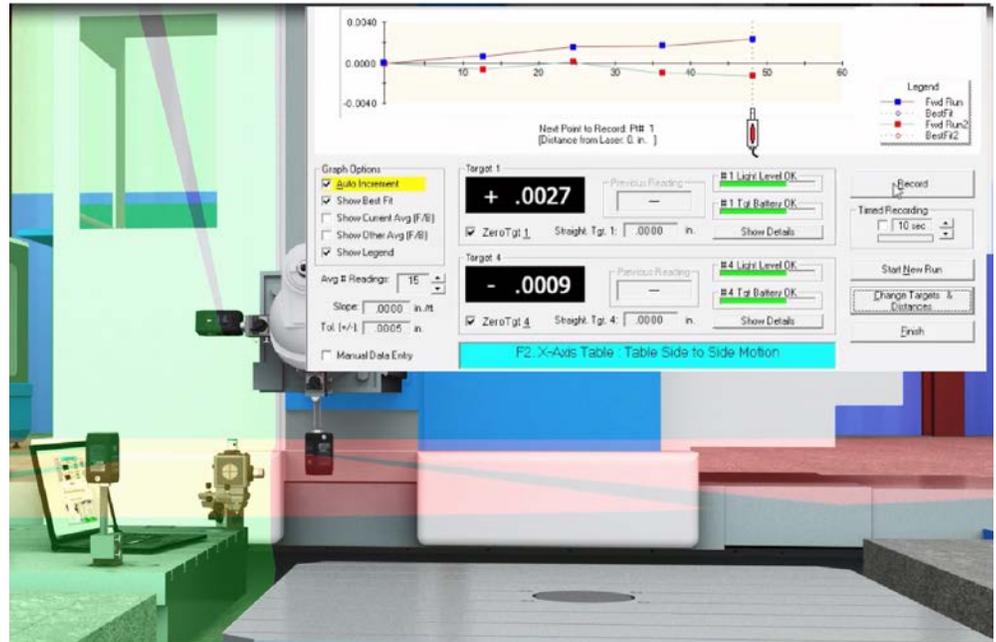
1. To set up for W, change the target position, turn on the laser rotation and adjust the spindle to center the laser.



2. Zero Targets #1 and #4. The green plane measures the straightness of W, W-X squareness and parallelism to Z (in X).

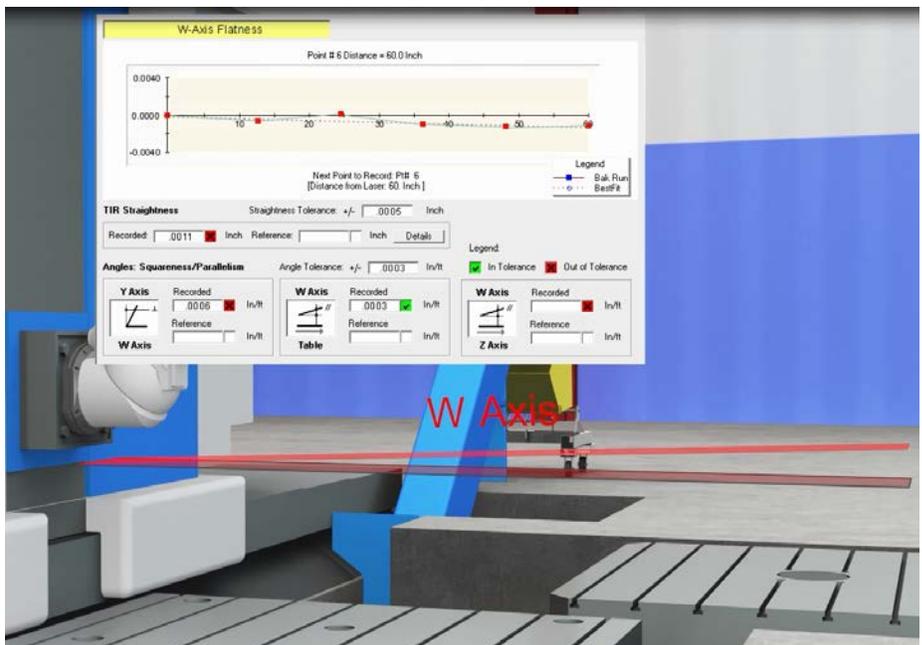


- The red plane measures the flatness of W, W-Y squareness and parallelism to Z (in Y). The software records the straightness of W and calculates the squareness and parallelism to the other axes. The results show .0003" for straightness and .0011" for flatness.



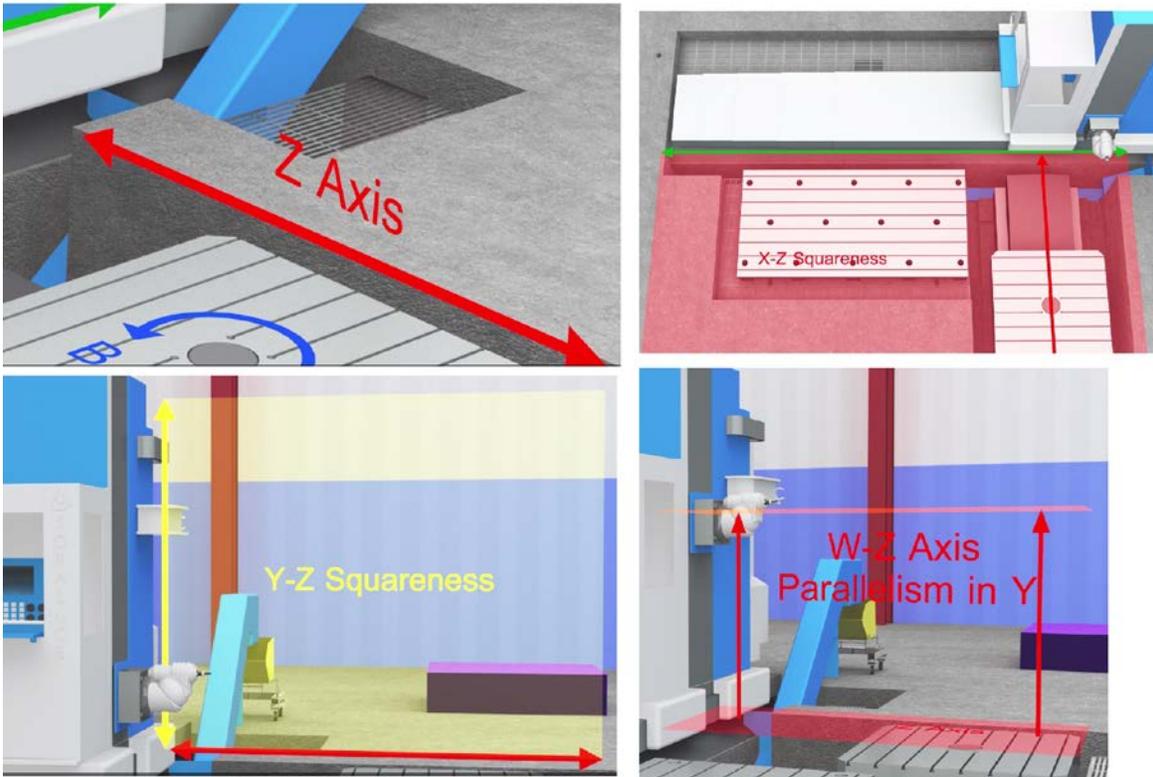
- The slope of the vertical Best-Fit line is .0003 in/ft., meaning the W-Axis is sloping up from left to right relative to the table.

For Z-W parallelism, Z must be measured first.

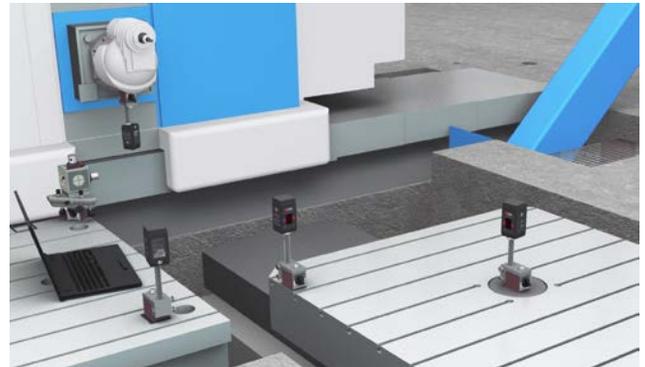


## Z-Axis Flatness and Straightness, Z-X and Z-Y Squareness, Z-W (in X) Parallelism, Z-W (in Y) Parallelism

The final axis check is Z-Axis flatness and straightness, which provides the squareness to the X-Axis and the squareness to the Y-Axis. In addition, the parallelism for Z-W (in Y) and Z-W (in X) can be determined.



1. Leave the laser in position and re-position the targets. To measure Z-Axis flatness, use the red laser plane with Target #1 on the table.



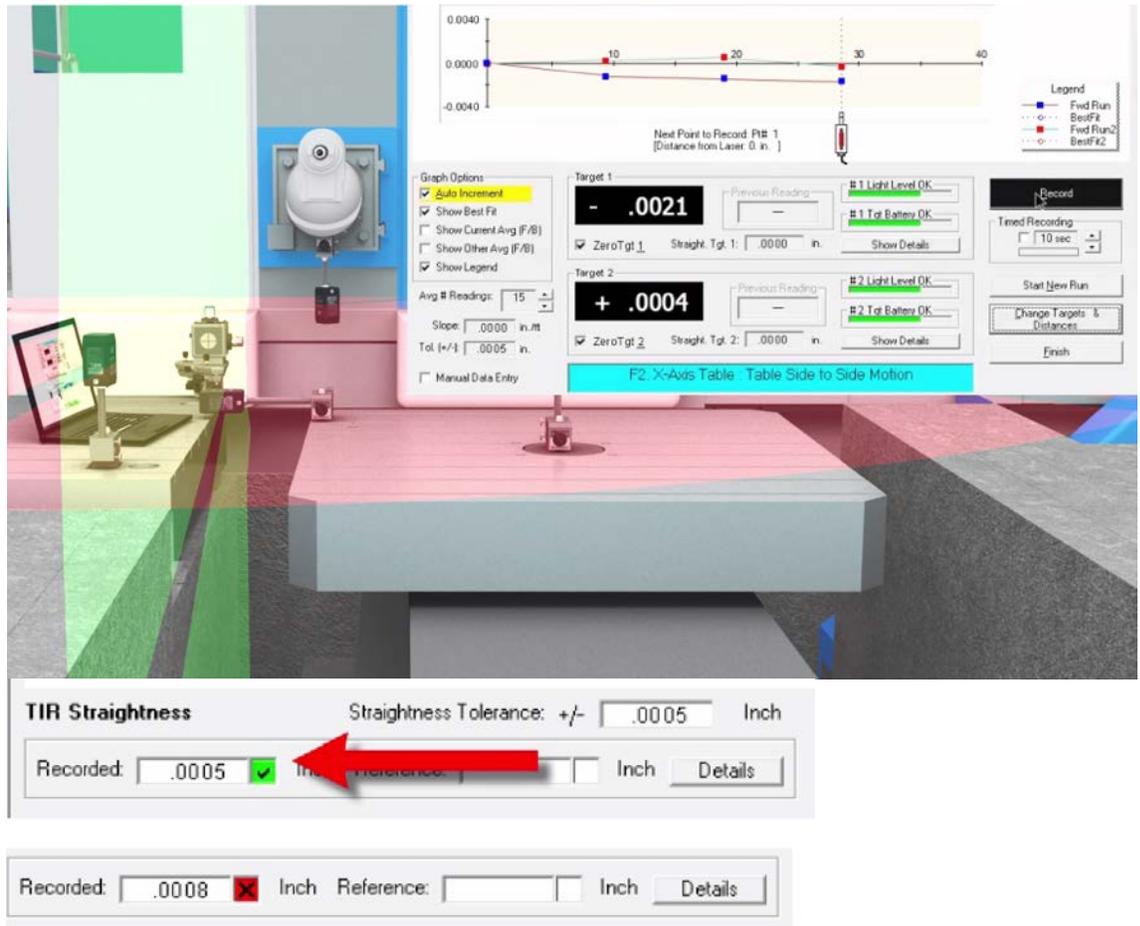
2. For straightness, mount Target #2's post into the side hole in the magnetic base to pick up the green laser plane. Adjust the pole length for Target #2, turn on the green laser and zero the display.

Repeat for Target #1 and the red laser plane. Now you're ready to measure.

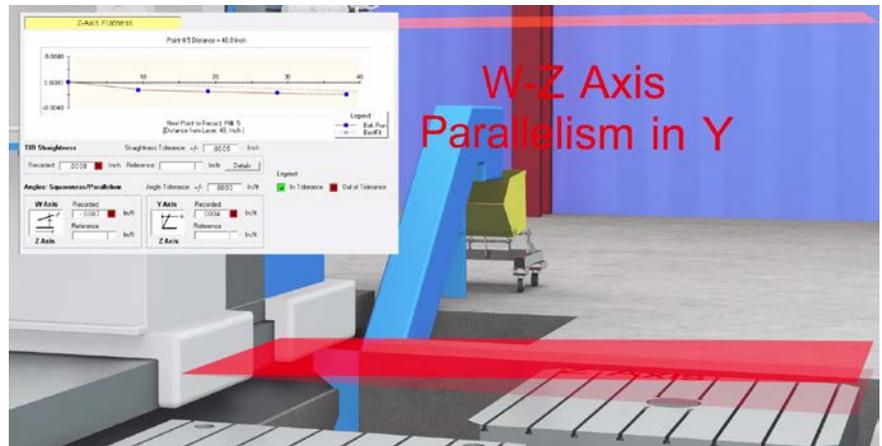


- Record the data in the Machine Tool Geometry program and the parallelism and squareness are automatically calculated.

The Z-Axis results show errors of .0005" for straightness and .0008" for flatness.



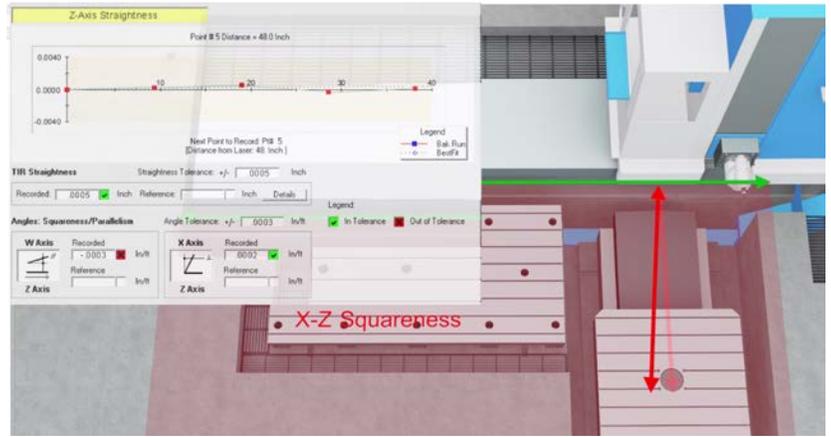
- The slope of the vertical Best-Fit line is  $-.0007$  in/ft., which means the Z-Axis is sloping up toward Y relative to W.



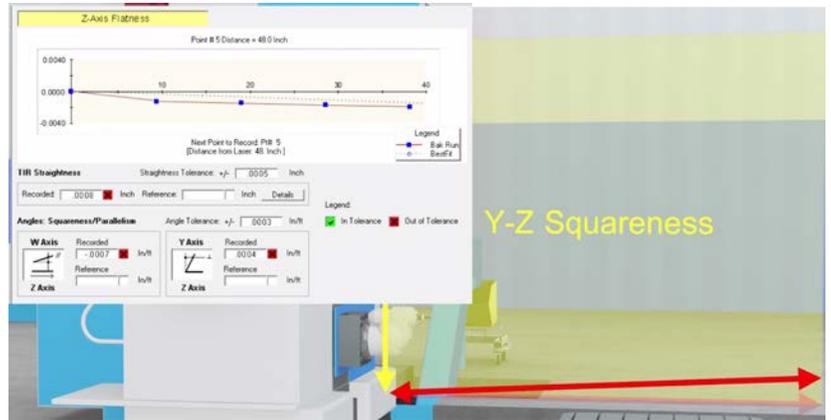
- The horizontal Best-Fit slope is  $-.0003$  in/ft, which means Z is sloping toward X relative to W.



6. For Z squareness to X and Y, the Machine Tool Geometry program subtracts the Best-Fit slope of Z from the Best-Fit slopes of Y and X and calculates the squareness. Therefore, the result for the squareness of Z to X is .0002 in/ft, which means the Z-Axis is tilting to the left.



7. The squareness of Z to Y is .0004 in/ft, which means the Z-Axis is sloping up relative to Y.



### Additional Capabilities of the L-743 Machine Tool Alignment System (Checking the A and B Rotary Axes and Trimming the Spindle)

- Rotation Flatness of Each Axis
- Squareness and Parallelism to Main Axes
  - A-X (in Z) Parallelism
  - A-Y (in Z) Parallelism
  - B-Z (in Y) Parallelism
  - B-X (in Y) Parallelism
  - Measuring the “tram,” or squareness of A’s spindle axis to X and Y

