Application Notes

Machine Tool Alignment

Machining Centers and Transfer Lines (Wing Bases)

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 to 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 ¼ 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 basic types:

1. *Straight-Line Laser Systems* - designed for lathe, turning center, bore and cylindrical grinding applications.
2. *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 accuracies 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.

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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 autocolimnator, 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.

Recommended System Configuration

L-743 Ultra Precision Triple Scan Laser
(3) A-1519-2.4ZB Wireless Targets
R-1355-2.4ZB PDA Display w/Read9 Software
L-106 Instrument Stand
A-809XL Shipping Case

Computer Accessories

A-910-2.4ZB Wireless Data Receiver
S-1387 Machine Tool Alignment Software for Windows
S-1388 Plane5 Software

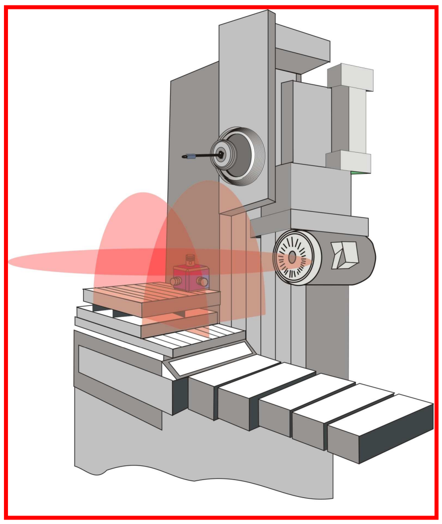
Optional Accessories

L-740SP Split prism upgrade to L-740 Series Lasers
L-106A Screw Lift
L-106XY 2-Axis Translation Slide
T-1500 Roll Alignment Floor Fixtures (set of 2) for use with the A-1519-2.4ZB Wireless Targets
R-1307W-2.4ZB Target Readout
R-1308 Auxiliary Readout

Another benefit of having a properly aligned machine tool is that part setup time is significantly reduced. An article in the October 1998 issue of Quality in Manufacturing Magazine describes the incredible benefit of laser alignment to the John Deere Corporation. In the words of Jim Abitz, tool and die maker, *"(Laser alignment) makes the operators a lot happier because they don't have to struggle for two or three shifts to get a machine to work properly."*

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 180º sweep and ¼ arc second (0.000015"/ft or 0.001 mm/M) in 90º sweep.



Column Squareness

Squareness Made Easy

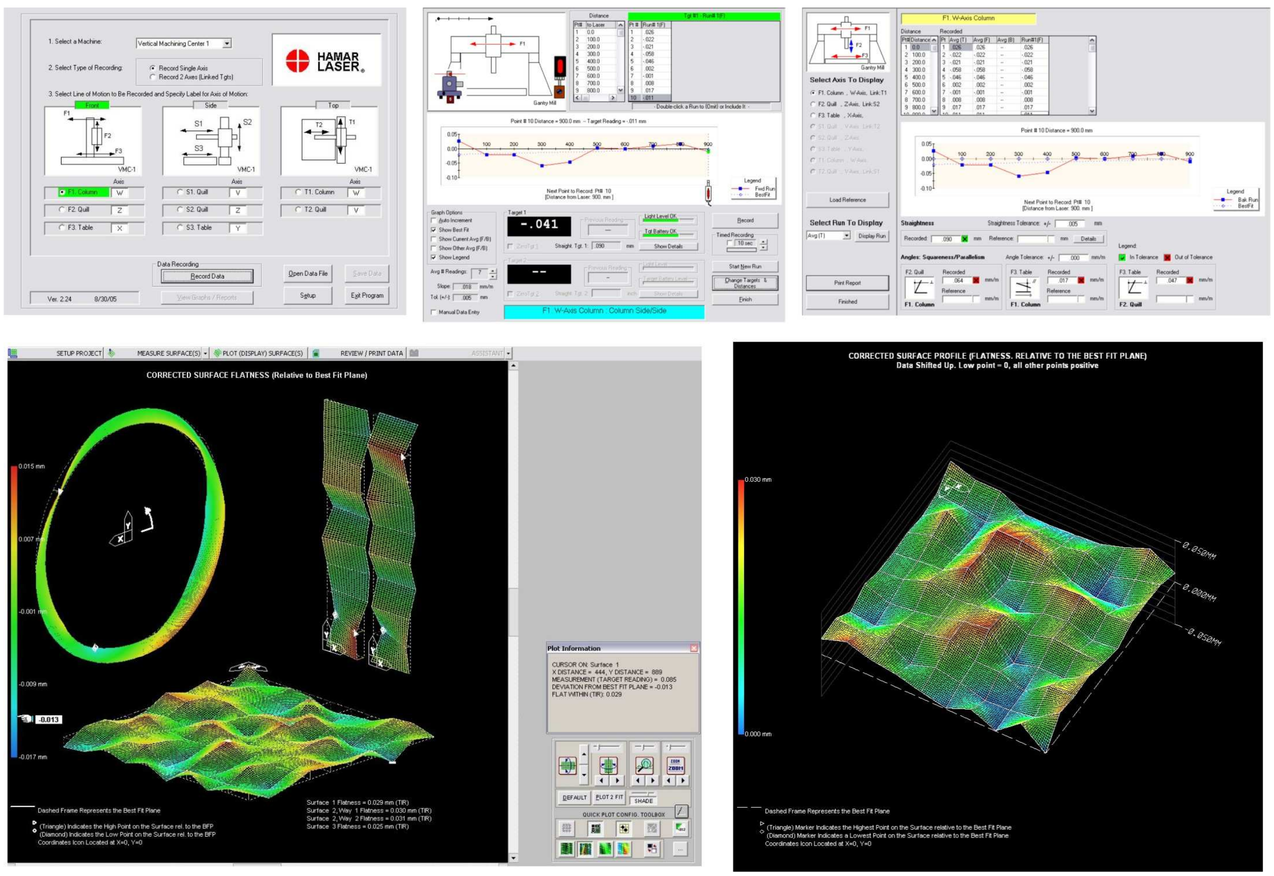
In addition, the L-743's three laser planes are square to each other to within 1 arc second (0.00006"/ft or 0.005 mm/M), providing a single reference from which to measure machine geometry. If you have ever tried to set up an interferometer to check squareness, you will be amazed at how quickly and easily 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.

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 ± .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 ½ arc second (0.00003"/ft or 0.0025 mm/M) in 180º sweep and ¼ arc second (0.000015"/ft or 0.001 mm/M) in 90º 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 ±.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.

Sample Summary of Alignment Report

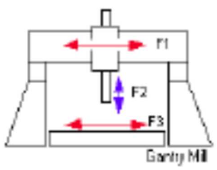
3D Plot

12-21-2011 10:09

Data Recorded: 12/21/2011 10:08:26 PM
Factory: MotoDrive Corp
Machine: 23456
Notes: gibs are loose!
Comments:
Center Units: mm
Slope Units: mm/m

Summary

Front View



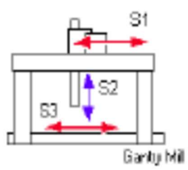
Straightness

Axis	TValue	Tol	Status
F1. Column	0.085	0.005	OUT OF TOLERANCE
F2. Quill	0.043	0.005	OUT OF TOLERANCE
F3. Table	0.047	0.005	OUT OF TOLERANCE

Squareness/Parallelism

Axis	Value	Tol	Status
F1. Column vs F2. Quill	0.035	0	OUT OF TOLERANCE
F1. Column vs F3. Table	-0.012	0	OUT OF TOLERANCE
F2. Quill vs F3. Table	0.047	0	OUT OF TOLERANCE

Side View



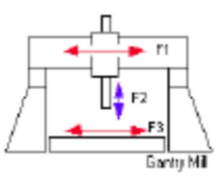
Straightness

Axis	TValue	Tol	Status
S1. Quill	0.029	0.005	OUT OF TOLERANCE
S2. Quill	0.076	0.005	OUT OF TOLERANCE
S3. Table	0.053	0.005	OUT OF TOLERANCE

Squareness/Parallelism

Axis	Value	Tol	Status
S1. Quill vs S2. Quill	-0.011	0	OUT OF TOLERANCE
S1. Quill vs S3. Table	-0.024	0	OUT OF TOLERANCE
S2. Quill vs S3. Table	0.013	0	OUT OF TOLERANCE

Top View



Straightness

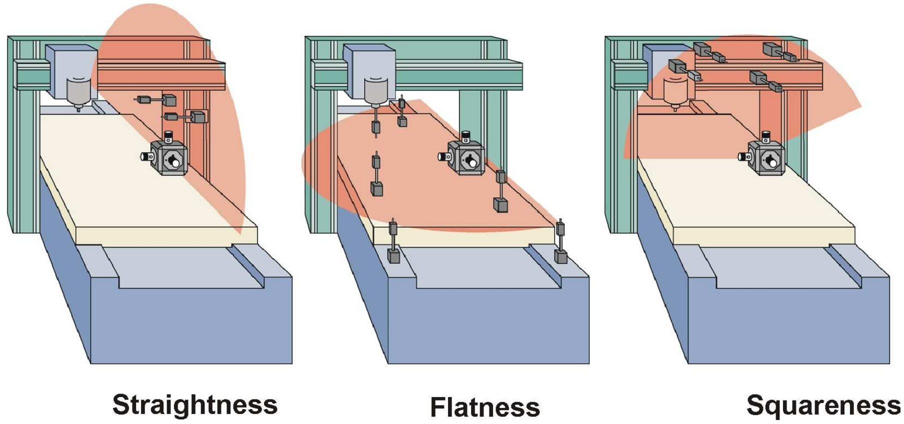
Axis	TValue	Tol	Status
T1. Column	0.133	0.005	OUT OF TOLERANCE
T2. Quill	0.087	0.005	OUT OF TOLERANCE

Squareness/Parallelism

Axis	Value	Tol	Status
T1. Column vs T2. Quill	-0.054	0	OUT OF TOLERANCE

How the Alignment System Works

The following section is describes how the laser is used to measure straightness, flatness, squareness, levelness and parallelism. 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, the user 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. In cases where only one target is used to set up the laser, the user must first determine what type of setup exists: close or remote. Please see the section at the end of this application note for a discussion on single target Buck-In. To speed up the setup process, the use of three reference target is highly recommended.

- For measuring straightness, two reference points are needed.
- For measuring flatness, three reference points are needed.
- For measuring the squareness (three areas) of a machining center, five reference points are needed.

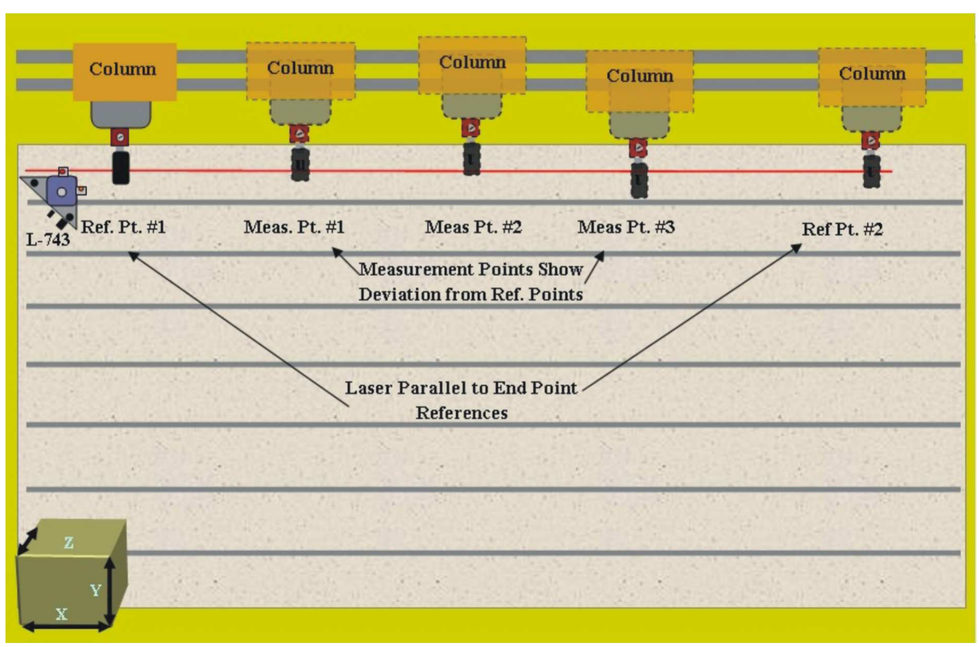
Once the laser has been set up to its reference points, the targets can be repositioned to measure the various surfaces or lines of motion for deviation from the references. A plus (+) reading indicates a target is higher than the reference points, and a minus (-) reading indicates it is lower.

Measuring Horizontal Straightness

To measure horizontal straightness of a surface or machine axis, two reference points and one vertical laser plane are needed.

L-743 Triplescan Laser Alignment System

Top View Showing X Straightness Measurement on Traveling Column Horizontal Machining Center



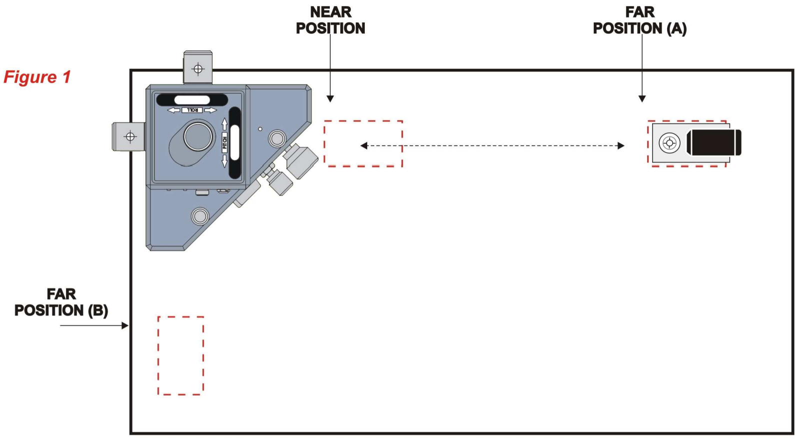
1. Mount a target horizontally at the *closest* reference point to the laser, either on the side of the table or fixtured into the spindle. Adjust the target so that it detects the laser.
2. Zero the target and move it to the *farthest* reference point from the laser until the target reads zero. Re-measure the initial reference point, re-zero the target, and repeat the procedure until the same reading is produced for both reference points. The laser is now parallel or "bucked in" or adjusted to the reference points.
3. Place the target at intervals along the surface or machine axis. Any deviations from zero are a measure of straightness relative to the reference points. If the target is mounted so that its top is to the left of the laser plane, then a "+" reading means the measured point is to the "left" of the reference points and a "-" reading means the point is to the right of the reference points.

Measuring Flatness

To measure flatness, a horizontal, continuously rotating laser plane is "bucked in" or adjusted so that it is parallel to three reference points on a table, set of ways, or a surface. The diagram below shows the setup for a 3-point buck-in using one target and multiple targets. The following procedure describes a 3-target buck-in:

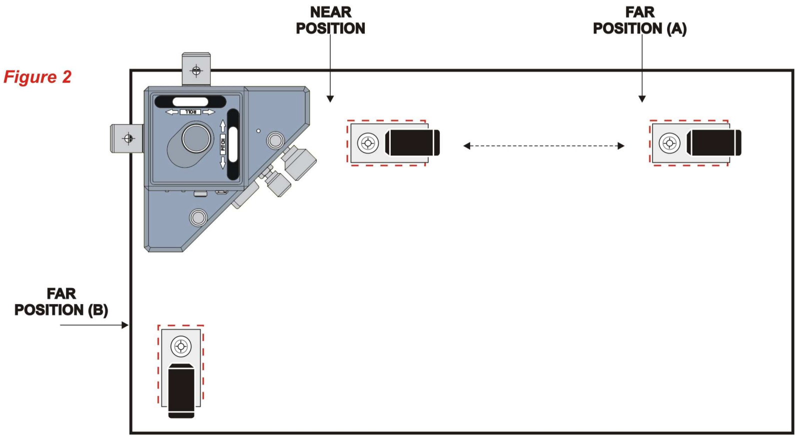
1. Place all the targets on one reference point one at a time and adjust them up or down so they detect the laser plane.
2. Zero the targets, one-by-one, on the same reference point.
3. Reposition the targets so that one target sits on each reference point, usually in an "L" pattern (*see Figure 2*).
4. Using the PITCH and ROLL adjustments, adjust the laser scan plane until all three targets produce the same value, thus making the laser parallel to the reference points.
   Note: This may also be accomplished by using one target, zeroed on the closest reference point to the laser, and moving it back and forth from the reference points until it produces a reading of zero at all three points (see Figure 1).
5. Re-zero one target on a reference point and move it to desired measurement points on the surface.
   The resulting reading is a measure of the deviation from the reference points, helping to produce a flatness profile. The measurement will show either a plus (+) or a minus (-) sign. A plus reading indicates that the target is *higher* than the reference points and a minus reading means the target is *lower* than the reference points.
6. Use Plane5 or 3DPlot Software to record and analyze the data.

Figure 1



3-Point Buck-in Using One Target

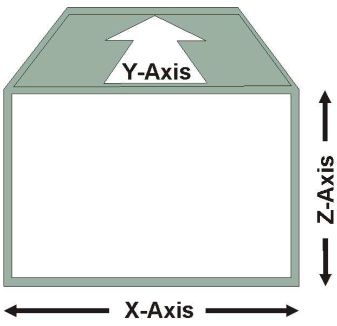
Figure 2



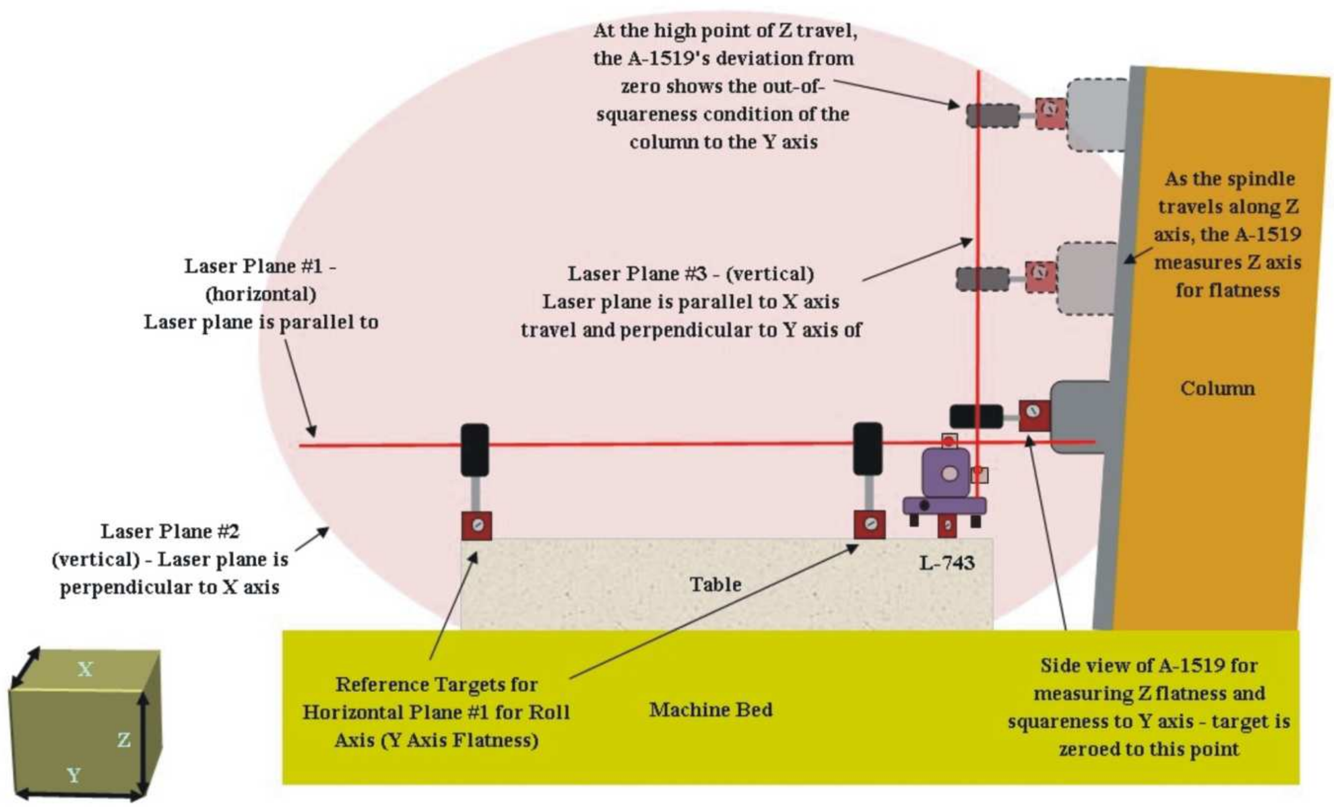
3-Point Buck-in Using Multiple Targets

Measuring Squareness

After bucking in the laser to the five reference points described in Measuring Straightness and Measuring Flatness, (to determine the straightness and flatness of the machine's axes) measuring squareness is a simple process of positioning targets on the column or the table, zeroing them and noting the deviations as the axis traverses. It should be noted that to *truly* measure squareness, one must compare the least-squares, best-fit line of the one axis to the other axis. If this is not done, bad reference points or severely worn ways might produce what looks like a squareness error, but in fact is not. To facilitate this type of analysis, our software programs may be used to automatically calculate the best-fit line.

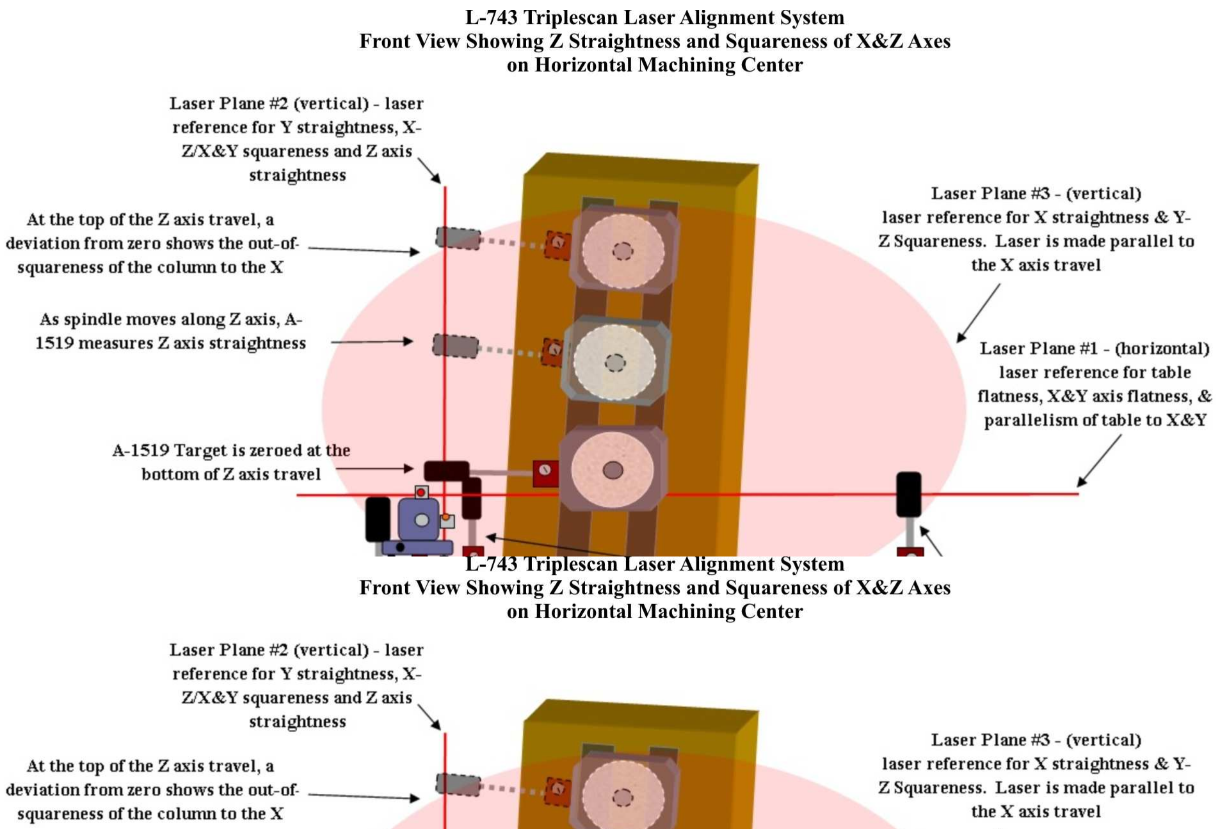


L-743 Triplescan Laser Alignment System
Side View Showing Z Flatness and Squareness of Y&Z Axes on Horizontal Machining Center



To measure Y-to-Z squareness (see figure above):

1. Lower the column/spindle to its lowest Z position and position a target horizontally to pick up the vertical laser plane that is parallel to the X-axis (perpendicular to the Y-axis).
2. Zero the target and traverse (raise) the column along its axis.
   The data produces a measurement of both the straightness of the Z-axis and the squareness of the Y-axis to the Z-axis.



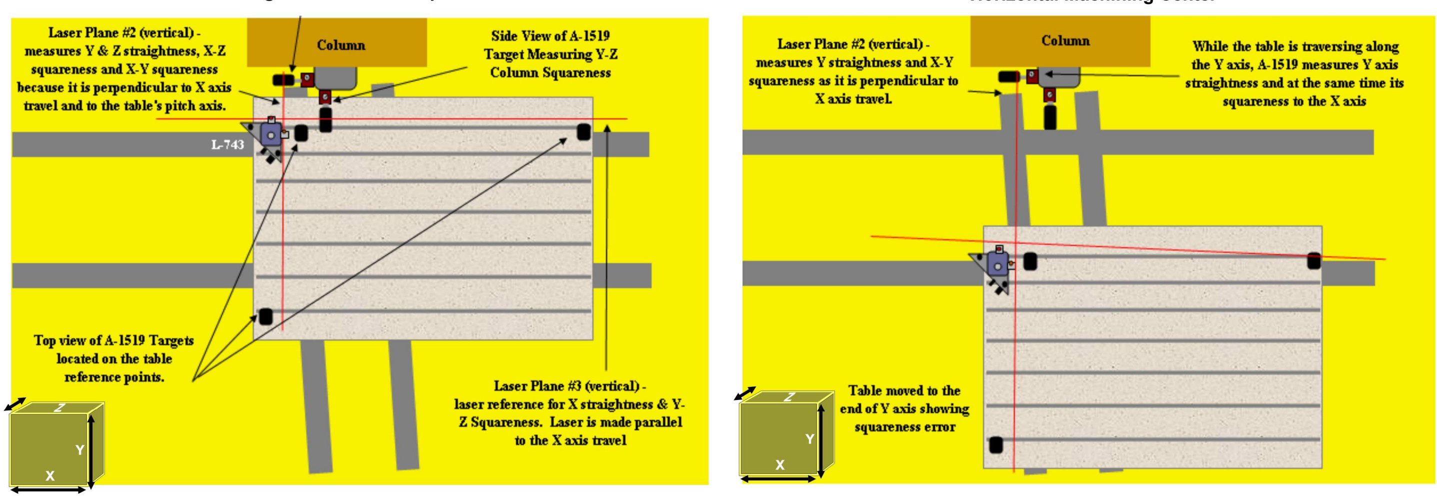
To measure Z-to-X squareness (see figure above):

1. Position and zero the target to detect the vertical laser plane that is parallel to the Y-axis.
2. Traverse the column upward. The resulting data is a measure of the Z flatness and Z-to-X squareness.

L-743 Triplescan Laser Alignment System
Top View Showing Laser Setup for Y-Straightness and Squareness of X and Y Axes on Horizontal Machining Center

Side View of A-1519 Target Measuring X-Z Column Squareness, Y Straightness and X-Y Squareness

Top View Showing Y Straightness and Squareness of X and Y Axes on Horizontal Machining Center



To measure X-to-Y squareness (see figures above):

1. Position and zero the target to detect the vertical laser plane that is perpendicular to the X-axis.
2. Traverse the table or column (whichever is moveable) along the Y-axis. The result is a measure of both Y straightness and X-to-Y squareness.

Measuring Levelness

1. Level the laser using the built-in level vials.
2. Place a target on one reference point, adjust it up or down so that it detects the laser plane, and zero the target.
3. Move the target to any other point on the surface to see the deviation of that point from the reference point relative to the level laser plane.

Measuring Parallelism

1. Buck in the laser plane to three reference points on the first surface (see *Measuring Flatness*).
2. Place a target on the second surface on one reference point and adjust the target so it detects the laser plane.
3. Zero the target.
4. Move the target to other points on the surface.
   Any deviation from the reference point is a measure of the parallelism of the first surface to the second.

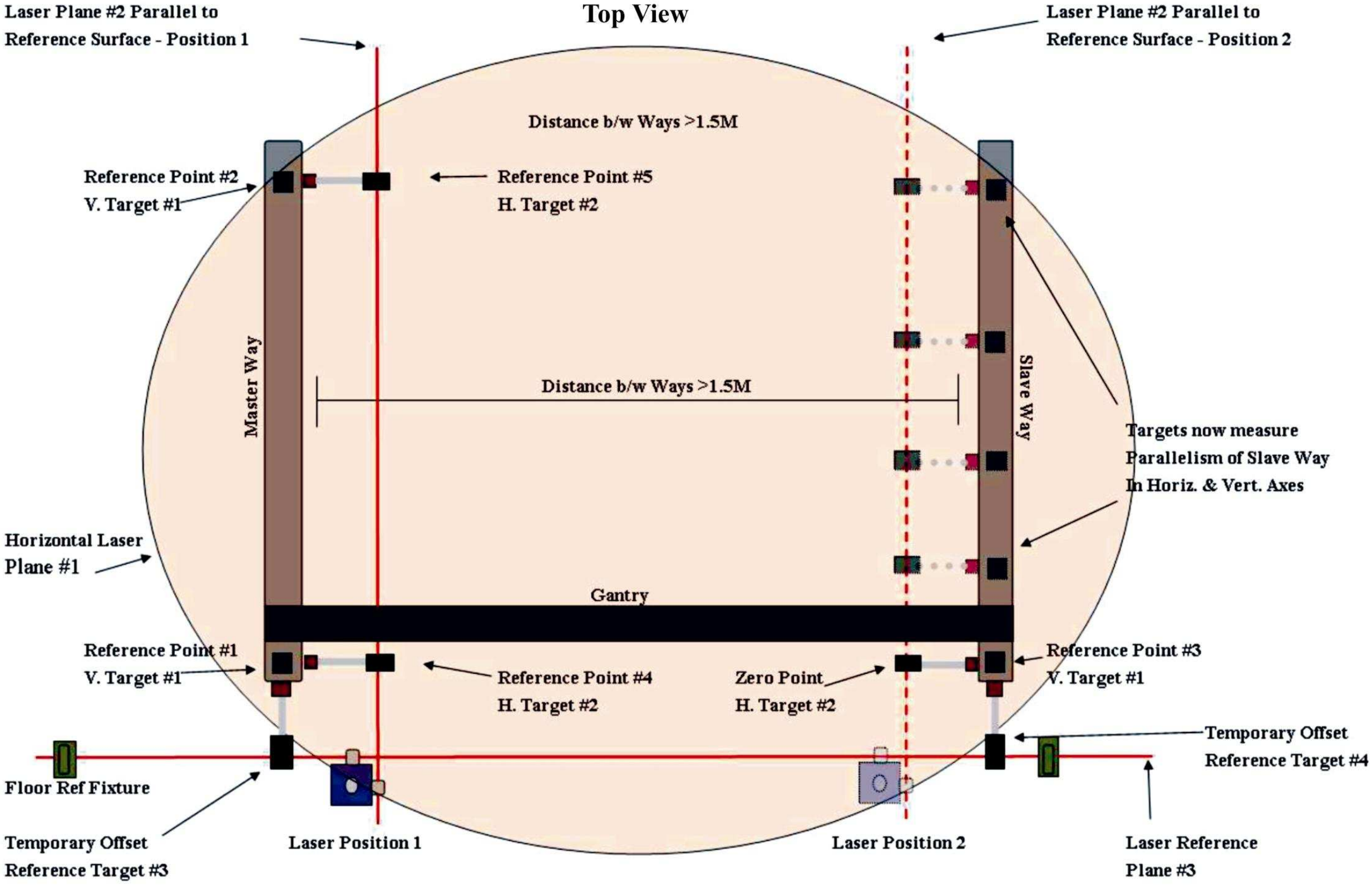
   Note: *At least three points should be measured. The best way to determine parallelism is to measure both surfaces with the laser plane and enter the data into Hamar Laser's* Plane5 *software, which calculates the least-squares best-fit plane for both surfaces.*

Checking Parallelism of Gantry Ways Using the Laser Transfer Method

The two drawings on the following page illustrate the Laser Transfer Method used to check the parallelism of gantry ways. Because the ways are generally 5-20 feet apart, the most difficult and time consuming part of aligning a gantry is checking the ways for parallelism. By using the L-743 Machining Center Alignment System with the following procedure, however, the setup, transfer of references and measurement of surface #2 should take no longer than 35-45 minutes.

1. Make the laser parallel to reference points #1-#5 on the reference surface, using the pitch and yaw adjustments in the laser base. This makes the laser parallel to three points on the top of the master and slave ways and two points on the side of the master rail.
2. Set up temporary reference targets #1 and #2 to pick up laser plane #2 and zero. This creates the reference line for the *roll* axis.
3. Set up two more temporary (offset) reference targets to pick up laser plane #3 and zero. This creates the reference line for the *yaw* axis.
4. Move the laser to the new location (laser position #2) and start turning the adjustment knobs until the laser plane #1 is parallel to reference points 1, 2 and 3 and laser plane #2 is parallel to offset reference points #3 & 4. This should take about 10-15 minutes.
5. When the laser is in position #2 and the laser planes are parallel to their respective references, place a fifth target on the second surface and zero to the laser.
6. Move the target to other points on the surface, and any deviation from zero is a measure of how far out of parallel surface #1 is to surface #2. Readings are live so the surface can be adjusted while the user watches it move on the handheld readout device.

Checking Parallelism of Gantry Ways
Laser Transfer Method
Top View



Laser Alignment Sketch for
Checking Way Parallelism
End View