White Paper

Inside the Trimble® X9 3D Laser Scanner

Deep Dive into Trimble X-Drive Technology

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Trimble

Why does the Trimble X9 3D laser scanner look so different from other scanners?

With no visible mirror assembly, the center unit resembles a total station more than a scanner. The X9 actually has the characteristics of both with a dual vertical drive system. The system integrates a survey-grade servo drive from a total station and a protected high-speed scanning mirror to enable features like auto-calibration and much more.

Does automatic self-leveling mean physically leveled without user intervention?

Trimble X9 self-leveling technology provides both full automation for quick setup and survey-grade accuracy for data you can trust. Some scanners measure level in all orientations without manually leveling, but they are not accurate. Others have survey-grade accuracy but use a tribrach to level within a tilt compensation range of 1 to 2 degrees. The X9 has survey-grade accuracy with a wide tilt compensation range of ±10° for easy setup with LED guide lights instead of a tribrach.

The purpose of this white paper is to explain the technology behind Trimble X-Drive and the many benefits it brings to 3D laser scanning. The following topics are covered:

- Trimble X9 Center Unit
    - X-Drive Vertical Deflection System
    - Automatic Self-Leveling
    - Integrated Camera System
- Summary of the Features and Benefits

Trimble X9 Center Unit

The center unit mechanical design drives the technical innovations of the Trimble X9. The protected center unit integrates a survey-grade servo drive with high-speed scanning, internal tilt sensors for self-leveling, a calibrated coaxial camera system for fast image acquisition and a laser pointer to facilitate geo-referencing, single shot measurements and field layout applications.

Figure 1: Trimble X9 protected center unit

X-Drive Dual Vertical Deflection System

X-Drive was introduced with the Trimble X7 laser scanning system as the world's first dual vertical deflection drive system, integrating a survey-grade servo drive with a high-speed scanning mirror. The concept of using a total station's well-known vertical servo system on top of a high speed deflection unit for scanning opens new features like auto-calibration, tilt measurements, and laser pointer. A total station vertical drive and angle encoder system is still integrated inside the alidade so the complete center unit, including the deflection unit and Electronic Distance Measurement (EDM) source, can be rotated around the trunnion axis in a traditional way like total stations.

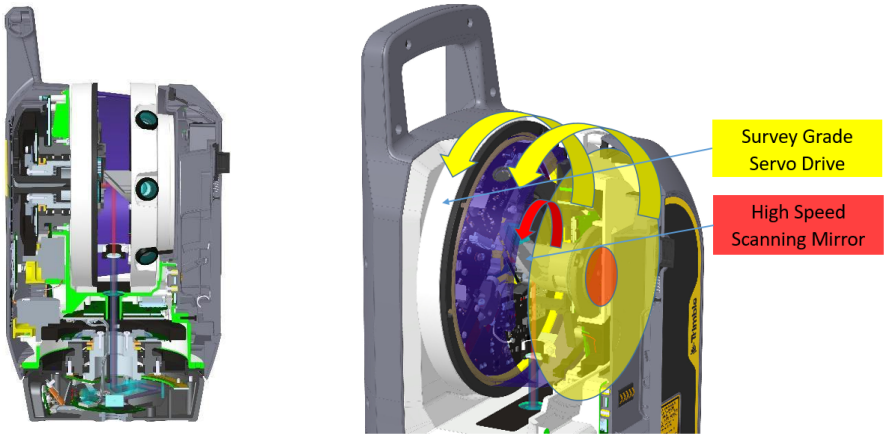


Figure 2: Dual vertical deflection system

The deflection drive is inspired by hard drive motor technology developed specifically for Trimble by industry experts in high-quality hard drives. The reliable drive has low friction, vibration, and power consumption, and is so quiet you won't hear the scanner running. The long life of the drive reduces maintenance cost and is one reason the Trimble X9 has a two year standard warranty.

Another mechanical feature is the 360° scanner window that protects the scanner's rotating deflection mirror. This special window is optimized for the EDM wavelength and has an anti-reflective coating for better signal transmission. The window has glass-like transparency but is impact- and temperature-resistant, perfect for demanding optical applications. The enclosed design helps the Trimble X9 achieve a reliable IP55 rating for dust and water jet ingress protection and safe operation with protection from the high-speed rotating deflection mirror.

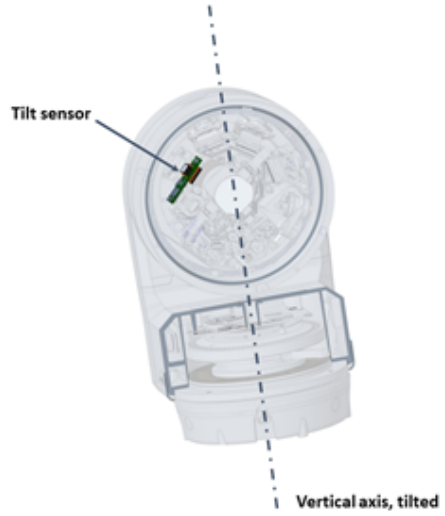
Figure 3: Protective window for rotating deflection mirror

Automatic Self-Leveling

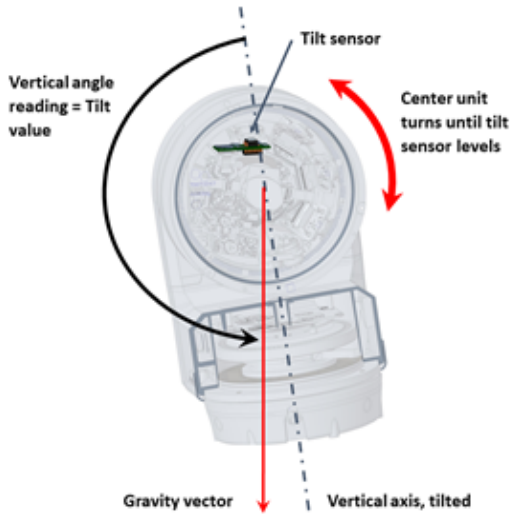
The Trimble X9 performs automatic self-leveling before each scan to automate field workflows. Precise leveling is one key for fast in-field scan registration and is a quality check to reduce errors and save time with minimal user interaction.

Traditionally, 3D laser scanners have either been challenging to level within range for survey-grade accuracy or unable to effectively achieve survey-grade accuracy. Scanners may have accurate sensors but limited range of measurement, requiring users to physically level the instrument with a tribrach to achieve survey-grade accuracy. This process takes time in the field and a certain level of expertise. Other scanners may have wide-range sensors with low accuracy so you can scan from any orientation, but you can't achieve survey-grade accuracy.

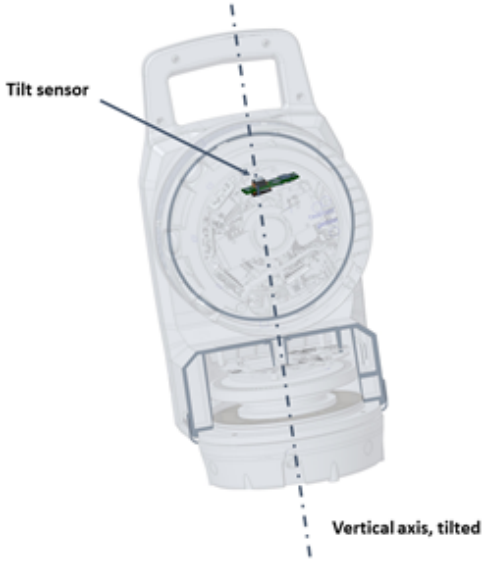
The X9 simplifies leveling with the automatic self-leveling process shown in the steps below.



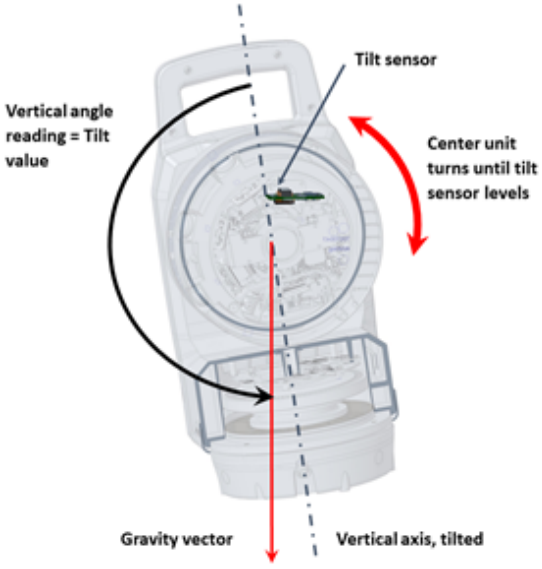
Step 1: Random position of center unit



Step 2: Center unit turns until tilt sensor is level



Step 3: Instrument rotates 180° around Hz axis



Step 4: Center unit turns until tilt sensor is level for second face reading

The system achieves survey-grade tilt compensation if the instrument is set up within a working range up to 10° from either side of its vertical axis for upright and upside-down scans. Scans are leveled with survey-grade accuracy of < 3" (arc seconds), which is equivalent to 0.3 mm @ 20 m. Setup within 10° is easy to achieve, but an option to enable guide lights is available to let users know if the tripod needs to be adjusted. This process is quick in the field and requires no expertise.

Survey-grade level data provides proof against survey truth. Self-leveling will ensure accuracy you can trust without targets or extra control on topographic surveys, floor flatness applications, or when monitoring the verticality of columns or walls during construction. For example, the verticality of a 10 m building will have an error of just 0.14 mm and the floor flatness of a 20 m floor will have an error of just 0.3 mm. Without survey-grade leveling, some scanners can have > 8 mm error at 10 m and >17 mm error at 20 m.

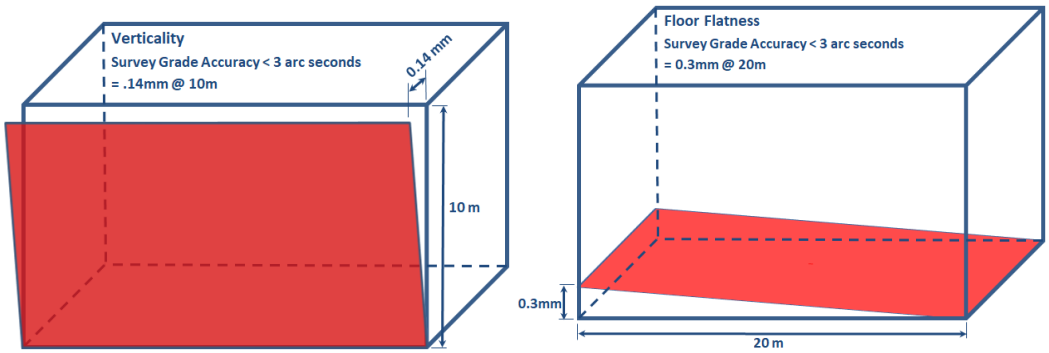


Figure 4: Survey-Grade Accuracy

Self-leveling must be enabled for in field registration. If the Trimble X9 is tilted more than 10° and up to 45°, the acquired scan will be roughly leveled, but not guaranteed the 3” accuracy. The scan will be flagged as "Not leveled," however Trimble Perspective field software can automatically register the scan if there is sufficient overlap with the scan you’re registering to. If the instrument is tilted > 45° from either side of its vertical axis, Perspective will display an error message and prevent scan acquisition. When the scanner is upside-down and the tilt is within a range of 10°of the vertical axis, the scan will be leveled with survey-grade accuracy and flipped automatically for correct orientation. The smart self-leveling also has real-time level monitoring to stop scans if tilt is disrupted during scan acquisition.

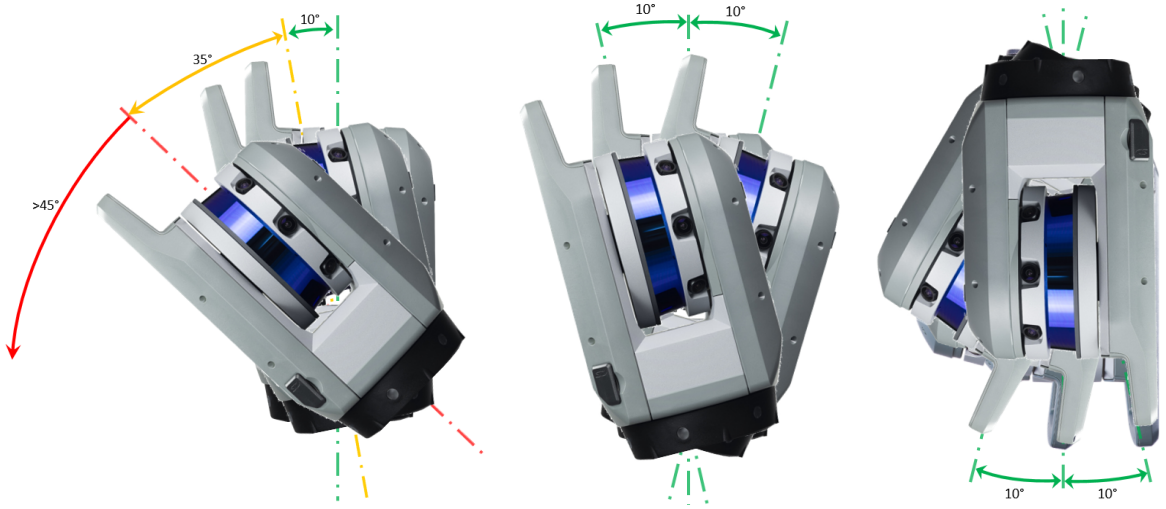


Figure 5: Scanner Orientations for Self-Leveling

Integrated Camera System

The Trimble X9 integrates a smart coaxial camera system with three 10 MP cameras. Resolution for each image is 3840 x 2746 pixels, each with a specific field of view to optimize coverage and productivity. The coaxiality of the cameras is given by mechanical design and the alignment of their optical axis to cross the center of our gimbal system to minimize parallax between images and scans.

Image acquisition time depends on the number of images selected. You have the option to capture 15 or 30 images. In normal lighting conditions, it takes one minute to capture 15 images and two minutes to capture 30 images with auto exposure. The 15 image capture takes pictures from six positions (rotating horizontally in 60° increments). The 30 image capture takes pictures from 12 positions (rotating horizontally in 30° increments). 30 images will enhance scan colorization and panorama image quality, especially in complex environments where occlusions are more prevalent. More images will improve coloring and coverage, however image capture and processing time will increase. 15 images are sufficient in simple environments where there are fewer occlusions and good quality coverage is possible.

There is also a High Dynamic Range (HDR) imaging mode that acquires two additional images at different exposures from each position and merges the results to achieve a higher range of luminance for more color and detail in bright and dark areas. HDR will take 3 minutes to capture 15 images and 6 minutes to capture 30 images.

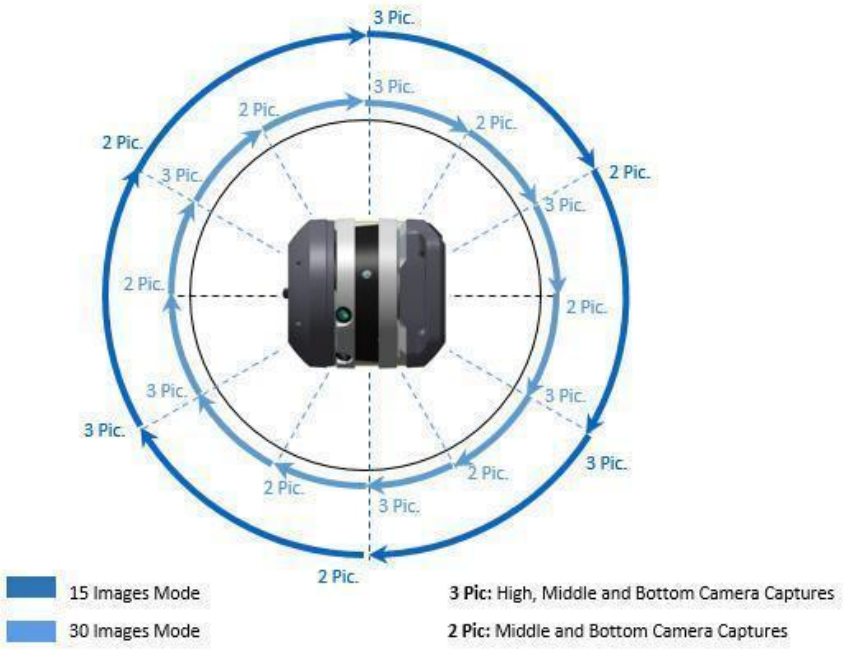


Figure 6: Positions for 15 and 30 image capture

Settings for white balance correction are available to remove unrealistic color casts so objects that appear white in the real world are rendered white in the image. Proper camera white balance has to take into account the color temperature of a light source, which refers to the relative warmth or coolness of white light. The Auto white balance correction is applied in the software and the indoor and outdoor presets are applied directly by the scanner. Here is a general guide for when to use each setting.

Auto—Recommended when lighting conditions are inconsistent

Sunny—Outdoors in bright sunlight

Cloudy—Outdoors on overcast days

Fluorescent—Indoors when bright fluorescent lighting is present

Incandescent—Indoors when more natural incandescent lighting is present

The colorization of scans and the creation of high-quality panoramas are done when projects are exported from the Perspective software. Single scans from the station list can also be processed in the field. Panorama creation will use the real point cloud distance to minimize mismatches and blending will smooth discontinuities between images and avoid object duplication. See indoor and outdoor samples below of panoramas and colorized scans.

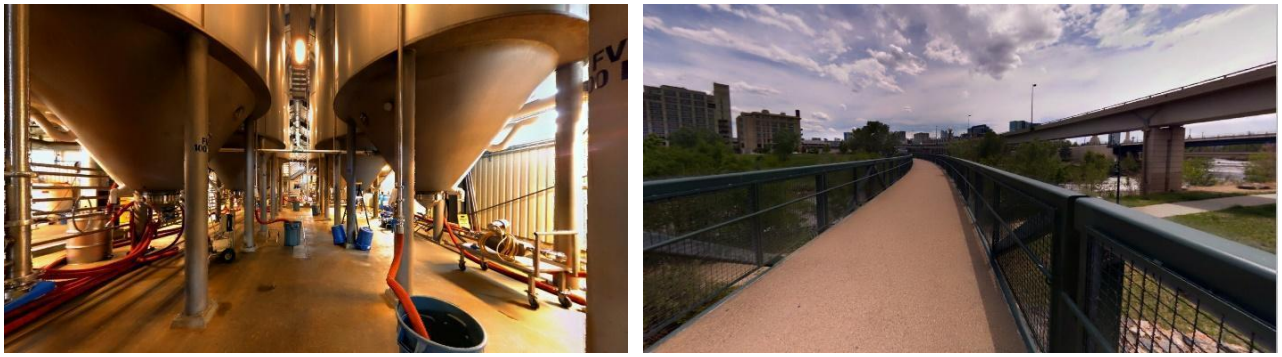


Figure 7: Panorama

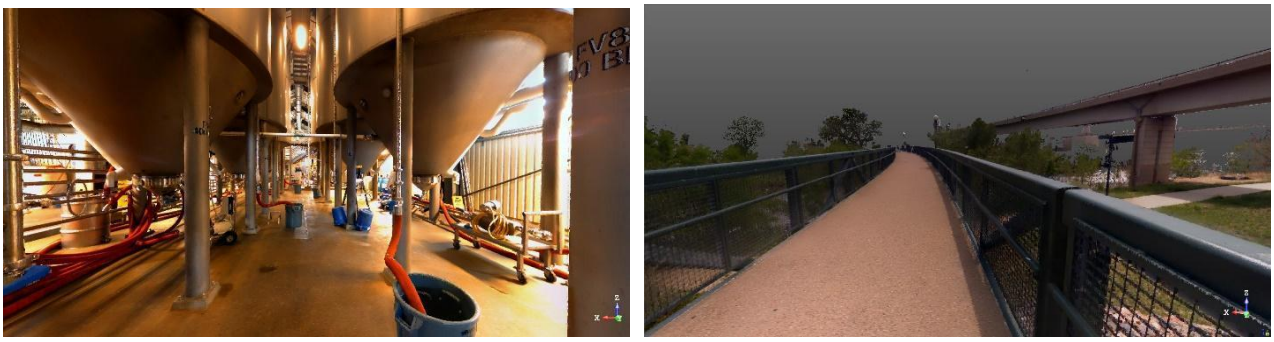


Figure 8: Colorized Scans

Laser Pointer

The Trimble X9 laser pointer locates points for Trimble Perspective precision point measurement and geo-referencing to link registered scans to a project coordinate system.

The laser pointer provides visual confirmation on a target in the field and can be precisely located in Perspective station views with the methods below.

A—Turn the station around its position in any direction to position the reticle over a desired position.
B —Tap in the reticle and tap left, right, up or down arrows to adjust the location in small increments in the corresponding direction until the laser point is at the precise in the field.
C—Tap a position within the station to move the reticle over the position.

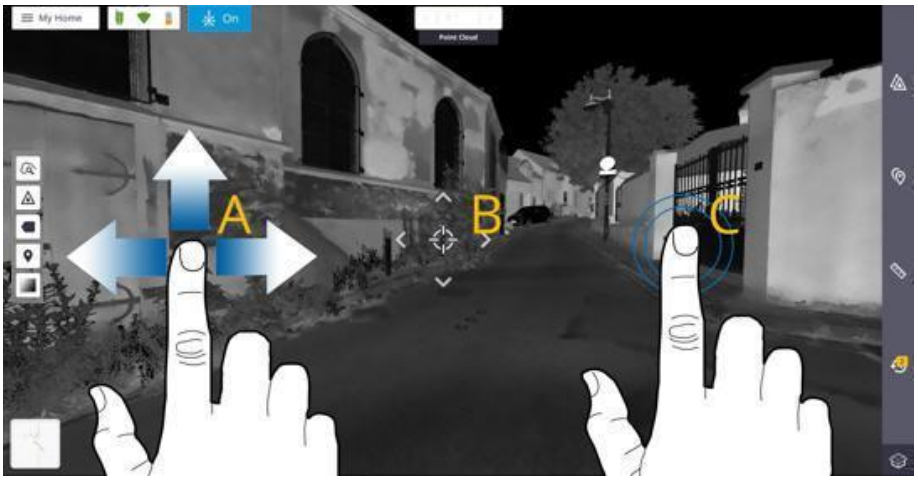


Figure 9: Locate the Laser Pointer in Perspective Station view

After you confirm the laser pointer is at the precise location in the field, you can accurately take the Precision Point measurement.

Figure 10: Visual confirmation of Laser Pointer on a target in the field

When you create a Precision Point, the X9 scans 21 points and averages the measurements for the most precise location of the point.

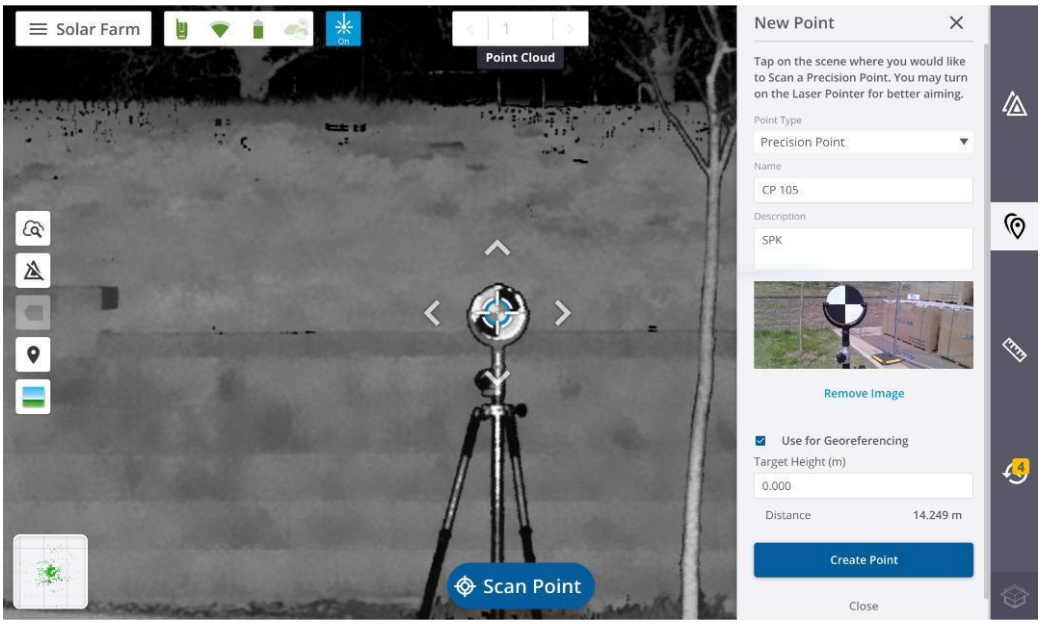


Figure 11: Create Precision Point in Trimble Perspective

Coordinates for precision points can be input manually or users can import survey control files to match locally observed points. When three or more control points in a given coordinate system match, you can apply survey control to the project and the registered scans will be georeferenced to that coordinate system. A globe icon will appear to indicate the project has been georeferenced.

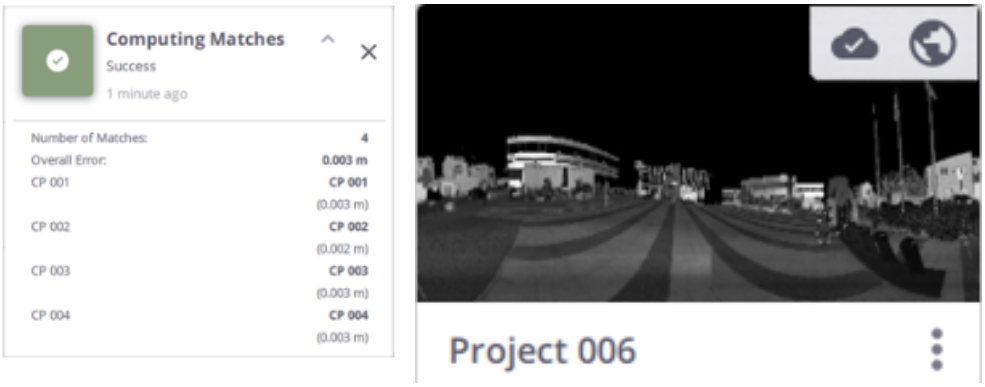


Figure 12: Compute matches with control points to georeference projects to a known coordinate system

Refer to the Trimble Perspective software Help file for more information on this topic.

Summary of Features and Benefits

Features	Benefits
Protected Center Unit	• Integrates high-speed deflection unit for scanning, internal tilt sensors, EDM source, camera system and laser pointer in one protected center unit • Optics protection in all weather conditions (IP55) • Safe operation
X-Drive Vertical Deflection Drive	• Integrates survey-grade servo drive with high speed scanning • Concept of a vertical servo system enables the entire center unit to rotate around the trunnion axis • Enables automatic calibration and self-leveling • Reliable; long life; low friction, vibration, power consumption, and noise • Enables industry-leading two year warranty
Automatic Calibration	• Ensures data accuracy from scan to scan • Angular and distance correction • Alidades encoder system adopted from total stations for precision • Accounts for alignment deviations inside the scanner head and adjusts to vibration and even shock • Smart calibration monitors environmental conditions and instrument temperature • Smart calibration only applies correction when required • No targets or user interaction required • No need for annual calibrations; reduces cost of ownership and accelerates ROI • Enables industry-leading two year warranty
Automatic Self-Leveling	• Survey-grade level compensation for both upright and upside-down orientations within range of ±10° • Survey-grade accuracy <3” = 0.3 mm @ 20 m • Scans with <45° tilt have coarse grade level accuracy • Real time level monitoring will not allow scan acquisition >45° tilt and will stop scans when level is disrupted • LED guide lights to verify verticality and levelness for fast easy setups
Integrated Camera System	• 3 x 10 MP cameras for fast image acquisition of 1 to 2 minutes • Quality full panoramas and scan colorization • Calibrated, coaxial cameras with optical axis aligned to center of deflection mirror to minimize parallax between images and scans • HDR and white balance correction to ensure image quality
Laser Pointer	• Geo-referencing • Single point measurements • Field layout applications

See the White Paper “Inside Trimble X9 Auto-Calibration” for more detail on the angular and distance calibration of this feature.

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