

VANTAGE

FARO Laser Tracker Vantage
User Manual
April 2016

FARO



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Chapter 1: Introduction

Thank you for choosing the FARO Laser Tracker Vantage. This document contains detailed instructions on how to use your Vantage with FARO Tracker Utilities software. Additional information about accessories and important guidelines on maintaining your new Vantage is also included.

This introduction contains information on how to reach FARO, how to read the manual, and a brief overview of the Vantage. If you have any questions or need further instructions about any procedure, contact your Customer Service Representative by Phone, Fax or E-Mail. See “*Technical Support*” on page 139.

Visit the FARO Customer Care area on the Web at www.faro.com to search our technical support database. The database is available 24 hours a day, 7 days a week, and contains hundreds of solutions to product and application questions. Listed below are some visual and typographical conventions used in each of the sections.

| | |
|------------------|--|
| Bold text | Indicates directory names, menu names, buttons, tabs, key names, acronyms, and modes. |
| monospaced text | Indicates alphanumeric characters or values you enter in a field on the screen. For example, “Type 0 . 005 for the tolerance setting.” |
| SMALL CAPS text | Indicates dialog box names, and dialog box items. |

You may also see a few new words. It is important that you understand the meaning of these words before proceeding.

| | |
|--|--|
| digitize | Indicates the recording of XYZ coordinates of a point or location in 3D space. The word digitize is the same as the term <i>measure</i> when referring to points. |
| choose or select | Indicates that you are initiating an action. For example, “Select File > Insert > CAD Parts .” |
| left-click, right-click, click, or press | Indicates that you press and release the corresponding mouse button or keyboard key. Also used when referring to the hardware device buttons. For example, “After selecting a file from the OPEN FILE dialog box, <i>click</i> OK to open the file” or “ <i>Press</i> ESC at anytime to cancel a command.” |
| drag | Indicates that you press and hold the left mouse button down and move the mouse. Release the mouse button to finish. This word is often used when changing the size of a window or toolbar. |

Warning

A **WARNING** notice denotes a hazard. It calls attention to an operating procedure, practice, or event that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a **WARNING** notice until the indicated conditions are fully understood and met.

Caution

A **CAUTION** notice denotes a hazard. It calls attention to an operating procedure, practice, or event that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a **CAUTION** notice until the indicated conditions are fully understood and met.

Note

A **NOTE** notice denotes additional information that aids you in the use or understanding of the equipment or subject. Specifically, they are not used when a **WARNING** or **CAUTION** is applicable. They are not safety related and may be placed either before or after the associated text as required.

General Information

The FARO Laser Tracker Vantage System is a portable, high accuracy, three-dimensional coordinate measurement device which has a measurement range of up to 80 meters (262 feet) with designated long range targets. The Vantage System consists of a Laser Tracker Measuring Head and a Master Control Unit (MCU). The Laser Tracker Measuring Head is compact, lightweight, quick to set up and to relocate, and is easily operated by a single person. The Master Control Unit is small, lightweight, and can be placed on the floor up to 3 meters (9.8 feet) from the Laser Tracker Measuring Head, or 10 meters (32.8 feet) with the optional extended cable.

The Laser Tracker Measuring Head emits an eye safe laser that a Retroreflector target, typically a Spherically Mounted Retroreflector (SMR), reflects back to the Laser Tracker Measuring Head and onto a position sensing detector. The position of the Laser Tracker Measuring Head's Azimuth and Zenith axis are continually updated using the feedback from this position sensing detector. The Laser Tracker Measuring Head has two rotary angular encoders and a laser-based distance measurement system. The coordinates of the target is determined by measuring the two angles and its radial distance.

The Vantage measures the radial distance to the target using a phase shift Absolute Distance Meter (ADM) system named TruADM. The TruADM system

allows the radial distance to be accurately measured in mid-air and allows the beam to be re-acquired in mid-air after a beam break has occurred. The Vantage also has an instant-on laser and is ready to work immediately after power up.

A fully-integrated weather station is standard with every Vantage system to ensure accurate radial distance measurement. A precision level sensor is also included inside the Laser Tracker Measuring Head allowing accurate measurement of the gravity vector.

The Vantage includes MultiView Cameras in the Laser Tracker Measuring Head that assist in acquiring a target after the beam has been broken or during point-and-shoot applications. These integrated cameras allow you to find targets by clicking near the target image on the screen. The MultiView Cameras are the main component of SmartFind, where the Vantage efficiently locates and locks the target after the operator moves the SMR in a specific manner or “gesture.”

The electronics inside the Laser Tracker Measuring Head and the Master Control Unit contain non-volatile memory used to store configuration, compensation and programming information required for easy and accurate measurements with the Laser Tracker. For security purposes, this memory does not store Laser Tracker measurements or pictures from the MultiView Cameras, and cannot be used to transfer information from one computer to another.

The FARO Laser Tracker Vantage System is IP 52 rated allowing you to use in demanding industrial conditions that may be exposed to water or large amounts of dust.

General Safety Information

The Vantage is a precision measuring device that is ruggedized for shop use; however, care must still be exercised in the operating environment when using the Vantage. Proper operation and care includes avoiding:

- Solvents.
- Opening the Laser Tracker Measuring Head and the Master Control Unit. There are no user serviceable parts.
- Aiming the laser at anything except a measuring target. See “*Laser Radiation Emission*” on page 6.
- Abuse such as dropping, or moving the Laser Tracker Measuring Head while the motors are on. See “*Motors*” on page 130.
- Power Fluctuations. See “*General Specifications and Rated Conditions*” on page 61.

CAUTION: The protection provided by this equipment can be impaired if using the Vantage in any manner not specified in this manual or other documentation.

Product Environmental Information

Legislation is now in place within the European Union (EU) that regulates waste from electrical and electronic equipment (WEEE). European Directive 2002/96/EC on Waste Electrical and Electronic Equipment (the WEEE Directive) stipulates that WEEE is now subject to regulations designed to prevent the disposal of such waste and to encourage design and treatment measures to minimize the amount of waste that is placed into the waste stream. The objective of the WEEE Directive is to preserve, protect and improve the quality of the environment, protect human health, and stimulate the practical use of natural resources. Specifically, the WEEE Directive requires that producers of electrical and electronic equipment be responsible for the collection, reuse, recycling and treatment of WEEE which the Producer places on the EU market after August 13, 2005.

FARO Technologies, Inc., as a producer of electrical and electronic equipment (EEE), has endeavored to meet these environmental responsibilities for managing WEEE. In so doing, FARO is providing the following to inform its customers about the WEEE collection process:

In order to avoid any potential dissemination of hazardous substances into the environment, FARO has labeled this product with the WEEE symbol (see below) in order to alert the end-user that it should be disposed of within the proper waste management system. That system will recycle, reuse, and dispose of materials from this product in an environmentally sound way.

The symbol represented below, and found on this FARO Technologies, Inc. product, indicates that this product meets the European Directive 2002/96/EC on Waste Electrical and Electronic Equipment. This symbol, only applicable in European Union countries, indicates that when this product reaches the end of its useful life it should not be disposed of with normal household or municipal waste, but in an established waste stream for WEEE.

Each EU Member State country has established a system for the collection, disposal, and recycling of WEEE. End-users in the EU should contact their local waste administration system for collection instructions concerning this product.

Refer to www.faro.com for further environmental information concerning this product.



WEEE Symbol

Chapter 2: FARO Laser Tracker Vantage Safety

The Vantage outputs a visible red laser beam. The source of the red light is an instant-on pointer beam which has an output of 1 milliwatt max/cw and is classified as a Class II laser. You should avoid direct exposure to your eye at all times even though the human blink reaction to bright light provides a natural mechanism of protection to this visible laser beam.

The Vantage's TruADM beam is an invisible infrared laser. The source of this beam is a distributed feedback (DFB) laser with less than 0.79 milliwatt output, and is classified as a Class I laser. This laser is harmless to your eye.

This equipment is classified as a Class II laser product and meets the requirements of the Food and Drug Administration, Center for Devices and Radiological Health, Register 21 CFR parts 1000 and 1040, and those of the international standard IEC EN 60825-1 2001-08.

The Vantage is certified to comply with the protection requirements of the Council Directives 89/336/EEC (Electromagnetic Compatibility) and 73/23/EEC (Low Voltage Directive on Electrical Safety) on the approximation of the laws of the Member States relating to Electromagnetic Compatibility, as amended by 93/68/EEC.

CAUTION: USE OF CONTROLS OR ADJUSTMENTS OR PERFORMANCE OF PROCEDURES OTHER THAN THOSE SPECIFIED HEREIN MAY RESULT IN HAZARDOUS RADIATION EXPOSURE.

The user must adhere to work safety laws as stated in UVV BGV B2, January 1993.

Laser Radiation Emission

When operating, a laser beam is emitted from the aperture on the Laser Tracker Measuring Head. See Figure 2-1 for the location of the laser beam aperture.



Figure 2-1 Laser Aperture

Laser Aperture Labels

The aperture warning labels indicate where laser radiation emits from the Laser Tracker Measuring Head. See Figure 2-2 for the locations of these labels. They

contain the words, “AVOID EXPOSURE, Visible and/or invisible laser radiation is emitted from this aperture.”



Figure 2-2 Laser Warning Labels on Aperture

Laser Emission Indicator

The emission indicator on the back of the Laser Tracker Measuring Head illuminates when the laser is energized and operating. See Figure 2-3 for the location of the laser emission indicator.



Figure 2-3 Laser Emission Indicator

Rear Composite Label

The composite label, located on the back of the Laser Tracker Measuring Head, combines the working logotype label, the certification label and the identification label into one. See Figure 2-4.

On the right side is the working logotype, which is required on all Class II laser products. It contains the wording:

LASER RADIATION, DO NOT STARE INTO BEAM.
632-663 nm Laser, 1 milliwatt max/cw.
CLASS II LASER PRODUCT.

To the left of the working logotype is the certification. It contains the wording:
PRODUCT COMPLIES WITH RADIATION PERFORMANCE STANDARDS
UNDER THE FOOD, DRUG AND COSMETICS ACT AND
INTERNATIONAL STANDARD IEC 60825-1 2001-08.

The bottom portion of the rear composite label contains the identification, which indicates the model number, the serial number, and the manufacturing date of your Laser Tracker System.



Figure 2-4 Rear Composite Label

Lifting the Laser Tracker Measuring Head

Follow safe lifting procedures when removing the Laser Tracker Measuring Head from its portable storage case. Always use safe lifting procedures when placing the Laser Tracker Measuring Head on, or removing the Laser Tracker Measuring Head from, the instrument stand.

- Use the retractable handle and the lifting recess area when removing it from the portable storage container.



Figure 2-5 Lifting the Laser Tracker Measuring Head

NOTE: You can also lift the Laser Tracker Measuring Head using the molded lifting grips on both sides of the Laser Tracker Measuring Head.

- Use the retractable handle and the lifting recess area when mounting and carrying the Laser Tracker Measuring Head.



Figure 2-6 Mounting the Laser Tracker Measuring Head

Pinch Points

Two labels that indicate pinch points are located on both the front and the back of the Laser Tracker Measuring Head's center eye wheel. Avoid placing hands and fingers in these pinch points. See Figure 2-7 for the location of the pinch point labels.



Figure 2-7 Pinch Point Labels

Hot Plugging

On the back of the Laser Tracker Measuring Head above the cable connection socket is the hot plugging caution label. See Figure 2-8 for the location of the hot plugging caution label.



Figure 2-8 Hot Plugging Label

The cable connects the Laser Tracker Measuring Head to the Master Control Unit.

CAUTION: *Do Not* connect or disconnect this cable while power is applied to the Master Control Unit (MCU). While the Vantage's electronics have protection against damage in the event of a hot plug or hot unplug, best practice is to have system powered off as hot plugging or hot unplugging may cause damage to the electronics inside the Laser Tracker System.

EMC Warning

Keep the Laser Tracker System and External Temperature Sensor cables separate from any other cables in the area in order reduce the likelihood of cross-coupled interference.

Two-way RF hand held transmitters may generate interference into the system. *Do Not* use these devices near the Laser Tracker System during measurements.

One-way RF transmitters, such as the RF Remote sold by FARO Technologies, Inc., *do not* cause interference.

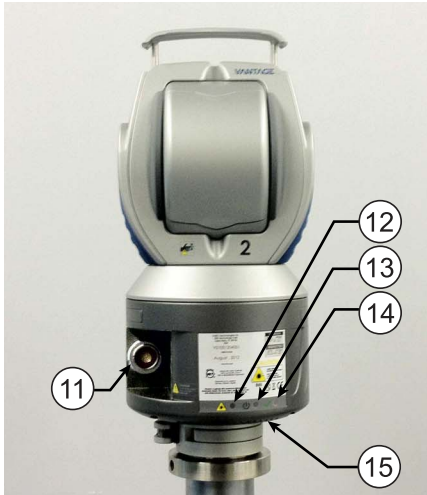
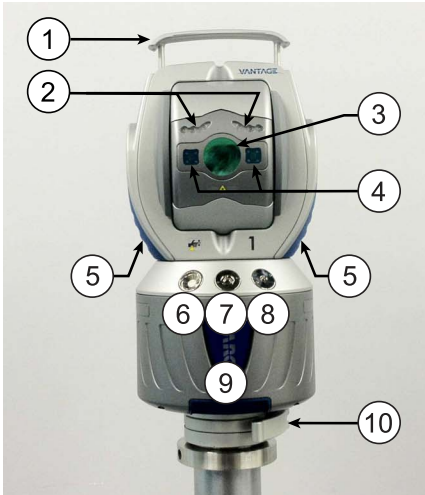
Chapter 3: The FARO Laser Tracker Vantage System

The major components of the Vantage system are the Laser Tracker Measuring Head, the Master Control Unit (MCU), a retroreflecting target, and the controlling computer running CAM2 Measure software or other measuring software.

NOTE: The Vantage is only compatible with CAM2 Measure v10.1 and later.

Laser Tracker Measuring Head

The Laser Tracker Measuring Head contains the tracker axis, lasers, optics, encoders, pressure and humidity sensors, and supporting electronics.



- ① Retractable Lifting Handle
- ② Indicator LEDs
- ③ Laser Aperture
- ④ MultiView Cameras
- ⑤ Lifting Grips
- ⑥ 1.5" SMR Home Position
- ⑦ 7/8" SMR Home Position
- ⑧ 1/2" SMR Home Position
- ⑨ Lifting Recess Area
- ⑩ Mandrel

- ⑪ MCU Cable Connector
- ⑫ Laser Indicator LED
- ⑬ Power Indicator LED
- ⑭ System Indicator LED
- ⑮ External Barometer Hose Test Fitting
(underneath base)

Figure 3-1 Laser Tracker Measuring Head
Front View

Figure 3-2 Laser Tracker Measuring Head
Rear View

Indicator LEDs

The Laser Tracker Measuring Head lights indicate the following:



- ① Red Aperture Light
- ② Green Aperture Light
- ③ Amber Aperture Light
- ④ Blue Aperture Light

Figure 3-3 Measuring Head Indicator LEDs

All Lights Blinking - Boot Sequence

Red Aperture Light

- Solid - Laser Tracker Measuring Head is measuring
- Blinking - Laser Tracker Measuring Head is measuring in scan mode (multiple measurements)

Green Aperture Light

- Off - Not locked on target
- Solid - Locked on target, valid beam and target position
- Blinking - Locked on target, invalid beam and target position

NOTE: Before the Laser Tracker Measuring Head is initialized the green aperture light may blink even if a target is not reflecting the beam back to the Laser Tracker Measuring Head.

Amber Aperture Lights - Application specific indicator

- Solid

- Slow Blinking
- Fast Blinking

Blue Aperture Lights - Application specific indicator

- Solid
- Slow Blinking
- Fast Blinking



① Indicator LEDs

Figure 3-4 Laser Tracker Measuring Head
Front Left View

Figure 3-5 Laser Tracker Measuring Head
Front Right View

NOTE: Events that the Blue and Amber Aperture Lights indicate are covered later in this and other FARO user manuals. *For more information, see “SmartFind” on page 134.*

Master Control Unit

The Master Control Unit (MCU) provides power and communication to the Laser Tracker Measuring Head. See Figure 3-6.



- ① Power Indicator LED
- ② Laser Emission Indicator LED
- ③ Temperature Sensor Ports
- ④ Primary/Secondary Indicator LEDs
- ⑤ External SYNC / Remote Input Trigger Port

Figure 3-6 MCU Front View

CAUTION: Vantage temperature sensors are not compatible with previous FARO Laser Tracker models ION, X, Xi, or SI. Notice that the Vantage temperature sensors have a green terminator on the cable. Temperature sensor from older FARO Laser Tracker models will not work with the Vantage.

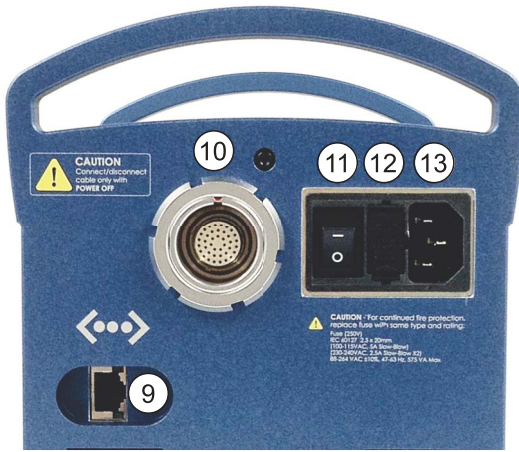
The front of the MCU has four (4) connectors for external temperature sensors, which can monitor the temperature of the ambient air or measured part. The right

side of the MCU has the AC power connection, the fuse drawer and the RJ-45 connection for the Ethernet connection to the computer. See Figure 3-8.



- ⑥ Ethernet Cable Connector
- ⑦ MCU Cable Connector
- ⑧ Power Switch

Figure 3-7 MCU right side







- ⑨ Ethernet Cable Connector with data transmission LEDs
- ⑩ MCU Cable Connector
- ⑪ Power Switch
- ⑫ Fuse Tray
- ⑬ AC Power Plug

Figure 3-8 MCU right side detail

For more information on connecting the MCU to the computer, see “*Hardware Configuration*” on page 121.

The MCU LEDs indicate the following:

| Symbol | Light Color | Function |
|---|-------------|---------------------------|
|  | Green | Power |
|  | Red | Laser Emission |
|  | Orange | Primary Indicator Light |
|  | Orange | Secondary Indicator Light |

The two orange (primary and secondary) lights indicate if the MCU is set to Primary where it will send a sync pulse to another MCU or Secondary where it will receive a sync pulse from another MCU. During the boot up sequence, it also indicates if the MCU is set to Wired or Wireless modes. When the MCU is switched on:

- Wired - The primary orange light is solid.
- Wireless - Both primary and secondary orange lights slowly blink for approximately two minutes, then the primary orange is solid.

For more information, see “Wireless Connection” on page 37.

Optical Targets

You can use a number of target types with the Vantage. The most common types are described below.

Optical Target Care

To operate properly the SMR must be clean. Refer to the *FARO Laser Tracker Optical Care Guide* or the *FARO Laser Tracker Accessories Manual* for cleaning details.

Spherically Mounted Retroreflector (SMR)

The Spherically Mounted Retroreflector (SMR) is the most commonly used target with the Vantage. It consists of a hollow cornercube mirror precisely mounted within a tooling sphere. The distance between the outside of the sphere and the center of the tooling sphere is known (the radius of the tooling sphere) and the CAM2 software, and many other software packages, use this value to offset, or compensate, measurements. SMRs are available in 1.5" (38.1 mm), 7/8" (22.225 mm) and 0.5" (12.7 mm) diameters. The SMR will reflect a laser beam with an incident angle of up to approximately $\pm 30^\circ$.



Figure 3-9 Spherically Mounted Retroreflector (SMR)

A colored ring band identifies each of the three SMR models available for each diameter size:

- **Black** - Standard Accuracy. The reflector vertex is centered within $\pm 0.0003''$ (0.0076mm).
- **Green** - Long Range. The reflector vertex is centered within $\pm 0.0003''$ (0.0076mm) and the dihedral angles have a tighter tolerance to permit the extended range.
- **Blue** - High Performance. The reflector vertex is centered within $\pm 0.0001''$ (0.0025mm) and the dihedral angles have a tighter tolerance to permit the extended range.

You can attach the SMR to a target adapter. The combination of the SMR and the adapter changes the compensation value. Use adapters to measure edges, inner and outer diameters and the position of bushed holes. There are a wide range of target adapters that are available on the FARO Electronic Product Catalog at www.faro.com. For more information, see "Probes" on page 122.

FARO RetroProbe

The FARO RetroProbe is an optional accessory product which greatly increases the versatility of the FARO Laser Tracker System. There are two versions of the RetroProbe: 100 and 400. The FARO RetroProbe 100 facilitates the measurement of surface features such as holes, small pockets, corners, and other features which are difficult or impossible to probe with the standard SMR. The FARO RetroProbe 400 expands on the versatility of the FARO RetroProbe 100 by providing easier manipulation of the device and allowing you to measure in locations up to four inches in depth.



Figure 3-10 FARO RetroProbe 400

Break Resistant Spherically Mounted Retroreflector (SMR)

Available in 7/8" (22.225 mm), 0.5" (12.7 mm) and 1.5" (38.1 mm) diameters, the Break Resistant SMR is an impact resistant target built with centering accuracy up to 0.0003" (7.6 μm) for the 7/8" (22.225mm) and 0.5" (12.7 mm) targets and 0.0001" (2.5 μm) for the 1.5" (38.1 mm) target.



Figure 3-11 Break Resistant SMR

Repeatability Targets

Use the Repeatability Target for repeatability and drift testing. Attach the target to a surface using hot glue or a similar adhesive, or use FARO part C-ACC-04140-000 - Repeatability Target Mount. Use this target only for repeatability measurements, **DO NOT** use it for accuracy measurements.



Figure 3-12 Repeatability Targets

Controlling Computer

A PC based computer running a Microsoft Windows operating system controls the Laser Tracker System. The computer communicates with the MCU using the TCP/IP network protocol in either Wired or Wireless mode. In Wired mode, the cable connecting the computer and the MCU is a CAT5 patch cable with a crossover for network communications terminated with an RJ-45 connector. In Wireless mode, the MCU connects to the computer using Wireless-N network adapter.

Software - CAM2 Measure

CAM2 Measure, is a CAD-based measurement and analysis software developed for use with a variety of 3D measurement instruments, including the Vantage. Use CAM2 Measure for simple go/no-go measurements or CAD-to-part comparison. CAM2 Measure allows you to measure details, create coordinate systems based on known datums, apply tolerancing (rectangular and GD&T), and create graphical reports. Simplify repeat inspections by creating a part measurement program which records all measurement instructions and then prompts a user through the entire inspection routine.

For more information about using the Vantage with CAM2 Measure, see “Configuring the FARO Laser Tracker Vantage in CAM2 Measure” on page 121.

Triggering Devices - RF Remote

The hand-held remote control is a wireless mouse with left and right click functions, and four auxiliary buttons. Program the buttons using the controlling software to perform basic Laser Tracker System commands from up to 30 meters (100 feet) away from the computer.

Refer the Assembly Instructions for the RF Remote, for setup and operation information.

External SYNC / Remote Input Trigger Port

The Vantage MCU has an External SYNC, or Remote Input Trigger, port that you can use to synchronize measurements with another controller, such as a robot, CNC, or other external device. An optional MultiUse Integrator Cable is available that connects directly into this port and has four (4) pairs of shielded wires on the opposite end for connecting to another controller.

FARO CAM2 Measure, FARO Tracker Utilities Measure Pad, and the FARO Software Developer's Kit support this port.

Remote Triggering

The trigger input to the MCU works by using a +3.3 Volt CMOS (+5 Volt tolerant) signal. The standard way to do this when using isolated contacts is to have the contacts normally open. This allows the internal 2.74 k Ω resistor pull the signal up to +3.3V. When the contacts are closed, the input is pulled down to ground making this an active low trigger. When the MCU senses this change, it records a measurement.

The trigger uses the Green/Black wire pair of the MultiUse Integrator Cable. The Black wire is connected to the internal Tracker ground and the Green wire is the trigger signal input.

NOTE: Only use the Black wire from the Green/Black pair. Using a Black wire from another pair can cause improper signaling. Isolate the remaining wire pairs to prevent a short circuit.

To trigger a measurement, FARO recommends opening the contacts for at least 1ms. The MCU records subsequent measurements for as long as the contact remains open.

Signaling Another Device

There are two options for the Vantage MCU to signal another device that a measurement has started, CMOS (+3.3V logic) and RS485 Differential.

1. CMOS

To use the CMOS output signal, use the Red/Black wire pair of the MultiUse Integrator Cable. Connect the Black wire to ground and connect the Red wire to the input device. The signal from the Red wire will be below +0.6V when measuring is active and higher than +2.2V when measuring is inactive.

NOTE: Only use the Black wire from the Red/Black pair. Using a Black wire from another pair can cause improper signaling. Isolate the remaining wire pairs to prevent a short circuit.

2. RS485 Differential

To use RS485 Differential, the Blue and Black pair of the MultiUse Integrator Cable are connected to an RS485 driver which provides a minimum 2 Volt differential output into a 100 Ohm load. The Black wire is (-) Negative and the Blue wire is (+) Positive.

NOTE: Only use the Black wire from the Blue/Black pair. Using a Black wire from another pair can cause improper signaling. Isolate the remaining wire pairs to prevent a short circuit.

Chapter 4: Key Components of the FARO Laser Tracker Vantage

Key components of the Vantage are the Weather Station, the two Angular Encoders and the Absolute Distance Measurement (TruADM) system.

Weather Station

The Weather Station monitors the temperature, pressure, and humidity at the location of the sensor. For the ADM system, the phase shift of the laser beam is a function of the frequency of the reference oscillator and the prevailing environmental conditions. Because the ADM depends on current environmental conditions to calculate the speed of light and convert the measured waves into a distance, the accuracy of the temperature, pressure, and humidity sensors must be established during factory calibration.

Temperature Sensor

Calibration of the remote temperature sensor for the Vantage is performed at the factory by comparing its readings to a NIST (National Institute of Standards and Technology) traceable precision standard temperature sensor.

Pressure Sensor

Calibration of the pressure sensor in the Vantage is performed at the factory by comparing its readings to NIST traceable precision standard pressure sensor.

Humidity Sensor

Verification of the humidity sensor in the Vantage is performed at the factory by comparing its readings to an independent relative humidity sensor.

Distance Measurement System

TruADM

TruADM is FARO's Absolute Distance Measurement system that uses patented predictive algorithms to compensate for the acceleration and velocity of a moving target, such as the SMR. Calibration of the ADM frequency oscillator is performed using the cesium clocks within the Global GPS Network. The ADM System is then factory compensated using a reference interferometer. After the

ADM System completes factory compensation, it is compared against an interferometer using the process defined in the American Society of Mechanical Engineers (ASME) B89.4.19 System Calibration. The interferometer used during these procedures is certified to NIST or other international recognized standards.

Certificate of Calibration

Included with every Vantage is a Certificate of Calibration that provides a Certification of the Laser Trackers ADM radial measurement system that is performed in accordance to Clause 6.4 of the ASME B89.4.19 System Calibration Standard. FARO's quality control process requires that several factory only compensations be performed followed by additional tests to verify Laser Trackers transverse system or angular measures within the accuracy specifications. FARO recommends annual recertification of the Laser Tracker. *For more information, see "Product Specifications" on page 61.*

If required by your company's quality control system or if you are interested in the calibration values of the transverse or angular system, an additional calibration performed in accordance to the full ASME B89.4.19 standard is also available. This calibration option is only performed upon completion of the Standard Calibration.

Spherically Mounted Retroreflector (SMR)

The accuracy of measurements made with the Vantage system depend on characteristics of the Spherically Mounted Retroreflector (SMR) such as:

- Ball diameter
- Vertex position
- Flatness of the optics
- Dihedral angle errors
- Reflectivity of the optics

The specifications for the Vantage system are valid when using SMRs certified by FARO. Mishandling of the SMR may change one or more of these characteristics and diminish the accuracy of the measurements taken with the Vantage. *See "Optical Target Care" on page 55.*

Chapter 5: Setting up the FARO Laser Tracker Vantage

This chapter describes the unpacking, mounting, connecting, powering up, startup checks, operational checks, compensations, and powering down of the Vantage System.

Unpacking the System

The Vantage Laser Tracker Measuring Head is packed in a shipping case. The Master Control Unit (MCU), cables, Spherically Mounted Retroreflectors (SMRs), tooling, and mounting hardware are packed together in a second shipping case.

CAUTION: When removing the Laser Tracker Measuring Head from the portable case, grasp the handle located on top of the Laser Tracker Measuring Head. You can also remove the Laser Tracker Measuring Head by grabbing the lifting grips on each side.

FARO Laser Tracker Vantage System Contents

The Vantage system includes the following:

Top Shipping Case and Master Control Unit (MCU) Backpack:

- Power Cable - a 120 or 240 VAC cable to connect the Master Control Unit to your source of electrical power.
- Communication/Power Cable - a 3 meter cable to connect the Laser Tracker Measuring Head and Master Control Unit.
- Remote Air Temperature Sensor - with 3 meter cable with a double-keyed connector that has 5 pins on the inside and a green boot on the outside.
- Computer to Master Control Unit Ethernet cable - 8 meter CAT5 100MHz crossover patch cable with RJ45 connectors.

NOTE: Bundle the power cable, communication/power cable, remote temperature sensor, and ethernet cable together inside Case #2.

- Master Control Unit (MCU)
- Quick Release Mandrel Mount - Allows for quick mounting to an instrument stand.
- Compensation Kit - equipment required for measurement and field compensation. Includes one tripod, and one tripod nest.

- Assembly Instructions - Vantage Assembly Instructions, Optical Target Care, Folding Tripod Assembly Instructions (optional).
- User Manuals - The following documentation is provided: Vantage Users Manual, and FARO Laser Tracker Accessories Manual.
- Dust Cover - A cover to protect the Laser Tracker Measuring Head when not in use. The cover is only necessary in very dirty environments.
- MCU Filter Kit - A cover to protect the MCU and a set of filters for the side vent areas of the MCU. These provide IP52 protection for the MCU.
- Documents - Certification documents showing traceability to NIST or other international standards.

Bottom Shipping Case and Laser Tracker Measuring Head Roller Board:

- Laser Tracker Measuring Head with integrated High Accuracy Level Sensor.

Optional Equipment

Your Vantage system may also include one or more of the following options:

- Various Optical Targets and Tooling.
- Remote Control Unit - Use this wireless RF remote control unit to control the FARO Laser Tracker Vantage system.
- Instrument stand (Tripod) - A stand that allows for easy height adjustment and movement of the Laser Tracker Measuring Head around the work environment, and provides stability during measurements.
- Uninterruptible Power Supply (UPS) - Protects the Laser Tracker System from power spikes and provides a battery backup during a loss of power.
- Remote Air and Material Temperature Sensors with 10 meter cable.
- Target Tooling Kit - Tooling for the 1.5" SMR. Includes drift nests, pin nests, a shankless nest, edge finders, etc.
- Extended Length Communication/Power Cable - a 10 meter cable to connect the Laser Tracker Measuring Head and Master Control Unit.
- Hot glue gun and glue sticks.

Unpacking

Unpack the Vantage system and your computer.

- **Shipping Cases**



Top shipping case:

- Master Control Unit (MCU)
Portable Storage (backpack)
case

Bottom shipping case:

- Laser Tracker Measuring
Head Portable Storage (roller
board) case

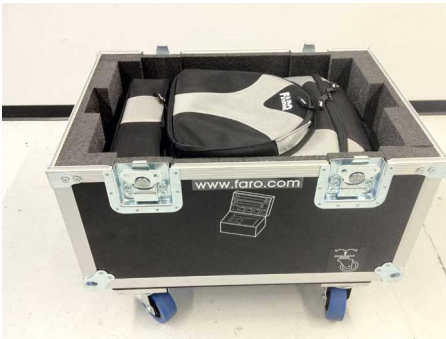
NOTE: This picture shows the Shipping Cases stacked and locked together - *Do Not* ship these cases stacked and locked together. Only stack and lock the shipping cases together when using the casters on the bottom shipping case for local transportation.

- **Portable Storage Cases**



Laser Tracker Measuring Head
Portable Storage (roller board)
case:

- Laser Tracker Measuring
Head



Master Control Unit (MCU)
Portable Storage (backpack) case:

Box 1:

- Mandrel
- Master Control Unit
(MCU)

Box 2:

- MCU power cord
- 3 meter communication/
power cable
- Ethernet Cable (cross-
wired)
- Remote Temperature
Sensor

Box 3:

- Optional Target Tooling
Kit

Mounting

You can mount the Laser Tracker Measuring Head in any orientation without affecting the accuracy of its measurements. There are three mounting options for the Laser Tracker Measuring Head:

1. Mount the Laser Tracker Measuring Head in the vertical position on an instrument stand or a trivet through the use of its mounting mandrel. Screw the mandrel onto the instrument stand using a 3.5"-8 UN-2B thread. Using the optional Side Mount and the mandrel, the Laser Tracker Measuring Head can be mounted in the horizontal position on an instrument stand.
2. The mandrel receptacle at the bottom of the Laser Tracker Measuring Head also has a bolt pattern that can also be used for mounting. This bolt pattern consists of four (4) 0.25"-20 UNC-2B holes spaced equally apart at 90 degree intervals. The bolt pattern forms a circle diameter of 3.125".
3. The receptacle at the bottom of the Laser Tracker Measuring Head is threaded into the bottom of the Laser Tracker Measuring Head. This receptacle can be removed to expose the same 3.5"-8 UN-2B thread as the mandrel. Removing the mandrel receptacle allows the Laser Tracker Measuring Head to be threaded directly onto an instrument stand or stand extension tube.

CAUTION: The mandrel mount is designed to hold the Laser Tracker Measuring Head in only the upright vertical position or in the horizontal position. To mount the Laser Tracker Measuring Head at any angle past horizontal, bolt it directly into a mounting fixture.

Setting up the Instrument Stand

Place the instrument stand on a stable floor surface away from obstructions. Ensure that the instrument stand is resting on its feet or adjusting pins. Screw the Mandrel onto a stable Instrument Stand, and tighten using the handle. Leave the handle in the open position to receive the Laser Tracker Measuring Head.

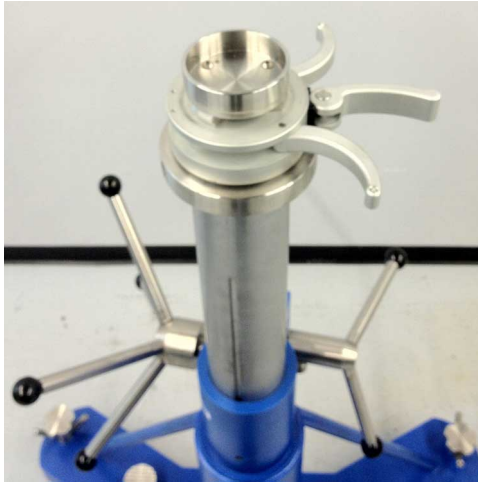


Figure 5-1 Tightening Side Lever

NOTE: For safety reasons, do not mount the Laser Tracker Measuring Head to a stand that is tilted more than 10° from vertical. When using the FARO Folding Stand with the legs in their lowest position, ensure that they are spread out as wide as possible with the center collar at the bottom of the center post. When the legs are extended, ensure that there is at least one meter between the legs for stability.

Mounting the Mandrel onto a Stand

The Vantage Mandrel allows you to attach the Laser Tracker Measuring Head onto an instrument stand or similar mount by threading the mandrel onto a 3.5"-8 UN-2B thread pattern. The mandrel has two levers that snap into its body that assist in threading or unthreading the mandrel from the instrument stand. To attach the mandrel onto the instrument stand:

1. Thread the mandrel onto the thread pattern.
2. Pull out the lever out from the side of the mandrel as shown in Figure 5-2. Use the lever to tighten the mandrel onto the stand.



Figure 5-2 Tightening Side Lever

3. When the mandrel is fully threaded onto the stand, snap the lever back into the side of the mandrel.

When measurements are complete, you can remove the mandrel from the instrument stand. To remove the mandrel from the instrument stand:

1. Pull out the other lever as shown in Figure 5-3. and use it to loosen the mandrel and unthread it from the stand.



Figure 5-3 Loosening Side Lever

2. After removing the mandrel from the instrument stand, snap the lever back into the side of the mandrel.
3. Pack the mandrel in Case #1.

Mounting the Laser Tracker Measuring Head

The locking lever for the mandrel has three positions:

- open
- partially open
- locked

These positions change the location of the brass engagement tab that locks the Laser Tracker Measuring Head into place.



Open Position



Partially Open Position



Locked Position

Figure 5-4 Mandrel Positions

Open Position

The open position allows the Laser Tracker Measuring Head to be placed on or removed from the mandrel.

Partially Open Position

The partially open position moves the brass engagement tab preventing the Laser Tracker Measuring Head from being placed on or removed from the mandrel, but you can still be easily rotate it on the mandrel. This position allows you to rotate the Laser Tracker Measuring Head so the three Tracker Mounted Resets (TMR) or Home positions are in a position where you can easily access during the measurements.

NOTE: If you are doing a Pointing Interim Test which requires measurements at specific Az angles, this makes it easier to rotate the Laser Tracker Measuring Head to obtain those angles as well. *For more information, see “Pointing Compensation” on page 94.*

Locked Position

The locked position completely engages the brass engagement tab and locks the Laser Tracker Measuring Head securely into place. This is the position that should be used for all measurements.

Check the complete Instrument Stand and make sure it is stable and tight. After the mandrel has been tightened, check the stability of the mount by trying to turn the base of the Laser Tracker Measuring Head. The Laser Tracker Measuring Head should not move with normal turning pressure. If the base of the Laser Tracker Measuring Head rotates easily on the mount, remove the Laser Tracker Measuring Head, check for debris on the mandrel or receptacle, and repeat the process. If the Laser Tracker Measuring Head still rotates easily, contact FARO Customer Service.

Cable Connections

Power for the Vantage Measuring Head is provided by the MCU - the Laser Tracker Measuring Head does not have a power switch.

1. Make sure that the power switch on the MCU is in the “**off**” position.
2. Remove the caps from each end of the 3 meter communication/power cable. Pull down on the connector sleeve to unlock the cap.
3. Connect the 3 meter communication/power cable to the socket on the back of the Laser Tracker Measuring Head and to the socket on the right side panel of the MCU.
4. Connect the remote air temperature sensor to port 1 on the front of the MCU.
5. Connect the computer to the MCU using the Computer to MCU Ethernet cable from the right side of the MCU to the computers network port.
6. Connect the MCU power cable to the MCU and a 120 or 240 VAC power source. FARO recommends to use an Uninterruptible Power Supply (UPS) between the power source and the MCU.

CAUTION: Follow the above steps to prevent “*hot plugging*” the main 3 meter communication/power cable if the MCU is already switched on. “Hot plugging” or connecting/disconnecting this cable while the MCU is turned on may damage the Laser Tracker Measuring Head or MCU. You can safely connect the Ethernet cable and the air temperature sensor when the system is turned on.

Computer Configuration

The Vantage requires a Pentium 4 PC (or better), running Windows 7 or Windows XP, with an Ethernet card.

1. Only one Ethernet card should be enabled, and the Windows firewall turned off.

2. Set your Ethernet card TCP/IPv4 to a static address of 128.128.128.10, with a subnet mask of 255.255.255.0.
3. The Vantage system's factory IP address is 128.128.128.100. Connecting to the MCU requires the supplied cross-wired Ethernet cable.
4. Start CAM2 Measure, open the DEVICE CONTROL panel, and add a FARO Laser Tracker Device. The default IP address for the Vantage is 128.128.128.100. *For more information, see "Hardware Configuration" on page 121.*

Wireless Connection

You can connect the MCU to your computer using a wireless LAN connection (WiFi) instead of the cross-wired ethernet cable. You must enable the wireless transmitter in the MCU and the wireless receiver in your computer. Each Vantage MCU has a unique wireless IP address and you will need to use the FARO Tracker Utilities (Diagnostics command) to find that address (169.254.xxx.xxx) to connect to CAM2 Measure.

NOTE: It is not possible to change the MCU's wireless IP address.

By default the MCU wireless operates in ad-hoc, or peer to peer, mode without any security.

MCU Configuration

In the factory configuration, the MCU wireless connection is Off. Use TrackerPAD to enable the wireless communication:

1. Start TrackerPAD. *For more information, see "TrackerPad" on page 124.*
2. Click the **Turn Wireless On** button.

NOTE: The text on this button is now **Turn Wireless Off**.

3. Note the name of the MCU's wireless network SSID (for example Vantage 2-12230) in the message box. You will need this name when you configure the wireless connection from your computer.

NOTE: The SSID number is the model name and the serial number of your MCU.

4. Power down the MCU, wait approximately 15 seconds, and power up the MCU. Notice that the Primary and Secondary Indicator Lights pulse together for approximately two minutes to indicate the wireless connection is active. After the wireless system start up is complete, the Primary or Secondary Indicator Light is solid.

Computer Configuration

The Vantage requires a Pentium 4 PC (or better), running Windows 7 or Windows XP, with a wireless receiver.

1. Configure your wireless receiver to connect to the MCU's wireless network SSID.
2. Start FARO Tracker Utilities and click the **Find Trackers** button in the TRACKER UTILITIES dialog box.
3. In the FIND TRACKERS dialog box, click the **Find Trackers** button. Write down the MCU's wireless IP address (169.254.xxx.xxx) or move the window over to the left side of the screen.
4. Start CAM2 Measure, open the DEVICE CONTROL panel, and add a FARO Laser Tracker Device with your MCU's wireless IP address (169.254.xxx.xxx). *For more information, see "Hardware Configuration" on page 121.*
5. Close the FARO Tracker Utilities.

Power Requirements

The Vantage will operate between 100 - 250 Volts RMS. The MCU has a worldwide power supply that automatically detects the voltage. However, the MCU requires has a fuse tray that is specific to the current voltage. If you are using the Vantage in region that uses a nominal line voltage of 240 Volts, you must use two fuses (2.5 Amp Slow Blow) in the MCU. If you are using the Vantage in a region that uses a nominal line voltage of 120 Volts, then one fuse (5 Amp Slow Blow) is required and the fuse tray has a spring permanently mounted where the second fuse used in the higher voltage regions would typically go. The Vantage ships with fuses and the fuse tray specific to the region. Fuse trays for other regions are available from FARO Customer Service.

The fuse tray is on the outside of the MCU and can be removed without any special tools. It is located between the power switch and the connection for the power cord. The size of the fuses is IEC 60127-2, 5 x 20 mm.

Powering Up

Apply power to the Vantage by pressing the switch on the right side of the MCU. Immediately after pressing the power switch, all six colored indicators on the front of the Laser Tracker Measuring Head light for a second and then go out. On the rear of the Laser Tracker Measuring Head, the Laser and Power indicator

lights and the System indicator flashes until the Start Up Checks are complete, and then remains lit.

The MCU's Power and Laser emission indicators also light.

NOTE: Apply power as soon as possible to begin the warm up. While the Laser Tracker Measuring Head is thermally stabilizing, you can prepare other aspects of the inspection, such as programming or additional tooling.

The Laser Tracker Measuring Head continues with the Thermal Stabilization and Laser Stabilization.

Thermal Stabilization

Immediately after applying power, the Laser Tracker System starts the “Thermal Stabilization.” During this time, the Power indicator on the back of the Laser Tracker Measuring Head will blink and the Azimuth and Zenith motors may have slight resistance. The Laser Tracker is taking this time to stabilize its internal temperature so accurate measurements can be taken in its current ambient environment.

The Vantage is an electromechanical device and will operate at an elevated temperature compared to the ambient air temperature. All laser tracker devices are required to warm up to achieve their specified accuracy as the sources of heat in the unit are not uniform and during the warm-up cycle the axis structure can change shape until a uniform operating temperature is propagated through all the structural parts.

The accuracy of the angular pointing system is most greatly impacted during the warm-up process so it is critical that the Laser Tracker Measuring Head is thermally stabilized before running any compensations. If a compensation is completed while the Laser Tracker Measuring Head is still warming up (if Thermal Stabilization is skipped), the system can drift out of tolerance as the axis structure continues to change shape working to the operating temperature and the stable geometry that is desired.

FARO's patented Smart Warm-up greatly reduces the required time for the Laser Tracker Measuring Head to achieve a stable operating temperature by monitoring internal and external temperature sensors and using the Laser Tracker Measuring Head's motors as heat sources.

The STARTUP CHECKS dialog box shows a timer showing the remaining amount of time for stabilization. When the Thermal Stabilization is complete, the blue light on the back of the Laser Tracker Measuring Head stops blinking. If measurement is required immediately, you can skip the Thermal Stabilization routine by clicking the **Skip Stability** button.

If the time to begin measurements is critical and Thermal Stabilization must be skipped, you must click the **Skip Stability** button in the first 2 to 3 minutes after powering on the system. Thermal Stabilization uses the internal motors as heaters and after 2 to 3 minutes, the heat generated from the motors will cause the geometry of the axis to change and can cause angular errors to exceed the system tolerance. The basic principal is to either skip thermal stabilization as soon as the system is powered on or let it run the full period. Thermal Stabilization has three sections of operation:

1. The first section uses rapid heating of the system using the motors to raise the Laser Tracker Measuring Head temperature to slightly higher than the target operational temperatures.
2. The second section is relaxation where the heat is allowed to equalize in the metal parts to provide a uniform and stable geometry of the trackers axis system.
3. If the Laser Tracker Measuring Head is not started when thermal stabilization is complete, it will automatically enter the third section where the operational heat is maintained by the system by running the motors at a minimal level until the Laser Tracker Measuring Head is started the motors are turned on for tracking.

NOTE: A Laser Tracker Measuring Head that is stored in an environment that is hotter or colder than the current measurement environment requires a longer Thermal Stabilization time than if the Laser Tracker Measuring Head was stored in the current measurement environment. When the Laser Tracker Measuring Head needs to cool down to reach operational temperature, it is often faster to allow it to soak in the environment for a period of time to cool off before powering on. While Thermal Stabilization will calculate the required time to cool down, the Laser Tracker Measuring Head naturally generates heat and will slow down the cooling process.

Startup Checks

Each time the Vantage is powered up, or when power to the system is interrupted, the system must be initialized or started. This is done through the Startup Checks which initialize the angular encoders and the position-sensing detector. The Startup Checks automatically run in CAM2 Measure software when the Vantage is started as the current input device. *For more information, see “Hardware Configuration” on page 121.*

1. Start the CAM2 Measure software.
2. CAM2 Measure software automatically starts the Startup Checks.

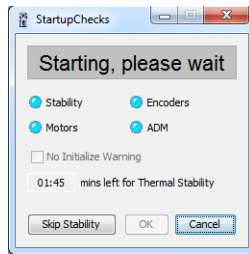


Figure 5-5 Startup Checks

NOTE: The Thermal Stabilization may more than 40 minutes to complete, depending on the initial temperature. You can skip Thermal Stabilization by clicking on the **Skip Stability** button.

Click the **OK** button to begin the Startup Checks. Keep your hands away from the Laser Tracker Measuring Head as the motors turn on and the top of the Laser Tracker Measuring Head rotates. This procedure takes approximately one minute.

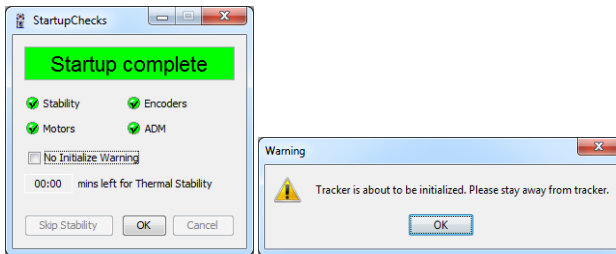


Figure 5-6 Startup Checks

The Startup Checks are now complete. Click the **OK** button to continue.

Interim Test and Compensations

Just as with all high accuracy precision instruments, the Laser Tracker System must be verified regularly. FARO CompIT's Interim Tests allow you to test the Laser Tracker System and its Compensations allow you to adjust the parameters when necessary. Compensations also address several potential sources of error and may be required after the Laser Tracker System has been shipped or subjected to impact.

The FARO CompIT chapter describes these compensations in detail. *For more information, see "FARO CompIT" on page 77.*

Angular Accuracy Checks

The Angular Accuracy Checks in FARO CompIT quickly checks the accuracy of the Laser Tracker System with minimal disruption of any measurements already in progress. Using Angular Accuracy Checks, you can check the accuracy of the Laser Tracker System anywhere in the measurement volume. This makes it possible to check the angular accuracy during the measurement of a part without moving or rotating the Laser Tracker Measuring Head. *For more information, see "Angular Accuracy Checks" on page 79.*

NOTE: Upon completion of Angular Accuracy Checks, CompIT may recommend a Quick Compensation to improve the Laser Tracker Measuring Head's accuracy.

Quick Compensation

Quick Compensation is a routine that corrects for angular measurement error. It is a single point compensation and is the fastest method of compensating the Laser Tracker System.

Click the **Quick Compensation** button in the CompIT main menu to start the routine. When complete (two to five minutes), the Laser Tracker System is within the pointing accuracy specifications and ready to measure. *For more information, see "Quick Compensation" on page 87.*

NOTE: After the Quick Compensation routine, Angular Accuracy Checks should be used to verify the accuracy. If an Angular Accuracy Checks was not performed immediately before the Quick Compensation, CompIT will recommend one be performed.

Pointing Compensation

The Pointing Compensation routine is the best and most accurate method to determine and correct for backsight errors, or angular measurement error. The Pointing Compensation takes more time and requires more space than the Quick Compensation, however it can produce the best possible Angular Accuracy results, especially at longer distances. It is either run from the Advanced tab of CompIT or when CompIT has determined that it is required based on the previous test results. There are two parts of Pointing Compensation:

- An Interim Test (IT)
- Compensations

The Interim Test uses measurements at predetermined locations and calculates the backsight error. After measuring, the system will pass or recommend to continue with the Pointing Compensation routines.

If obstructions prevent the measurement of any remote points, rotate the Laser Tracker Measuring Head on its stand. *For more information, see “Pointing Compensation” on page 94.*

ADM Checks

The ADM (Absolute Distance Meter) Checks verifies the accuracy of the ADM radial measurement. By comparing the ADM measurement to the angular measurement of the Laser Tracker Measuring Head. *For more information, see “ADM Checks” on page 105.*

Powering Down

Use the following steps to power down the Laser Tracker System:

1. Store the SMR and other targets in their protective cases.
2. Exit the CAM2 software and shut down the computer.
3. Press the switch on the right side of the MCU to power down the system.
4. Disconnect the MCU power cable from the power source and the MCU.
5. Disconnect the remote air temperature sensor from port 1 on the front of the MCU.
6. Disconnect the Computer to MCU Ethernet cable from the right side of the MCU and from the computers network port.
7. Disconnect the communication/power cable from the back of the Laser Tracker Measuring Head and from the right side panel of the MCU.

8. Pack all cables into the Portable Storage case.
9. Move the Mandrel handle to the open position. Using the retractable handle and the lifting recess area, lift the Laser Tracker Measuring Head off the Mandrel and place it into the Portable Storage case. You can also lift by grabbing the lifting grips on each side.

Connection Problems

This section covers troubleshooting and solutions to common connection problems between the Vantage and your computer. Remember that the normal IP settings for the Vantage and your computer are:

- Computer Local Area Connection - set IP address of 128.128.128.10.
- Computer Wireless Network Connection - Automatically set IP address.
- Vantage Local Area Connection - set IP address of 128.128.128.100.
- Vantage Wireless Network Connection - unique IP address of 169.254.xxx.xxx.

Cannot connect to the computer using the Ethernet cable.

- Make sure the ethernet cable is the cross-wired type for the Vantage.
- Disable any additional ethernet network cards installed in your computer.
- Set the TCP/IP v4 properties of your adapter card (Local Area Connection) to the specific address of 128.128.128.10.
- Turn off the Windows Firewall or any 3rd party software firewalls.
- Power off and power on the MCU and check that the Primary and Secondary lights are not flashing to indicate that the MCU wireless is on.
 - If the wireless is on, connect to the MCU using the wireless and use FARO Tracker Utilities to turn wireless off, or perform a MCU quick reset.

Unknown wireless IP address and wireless is on.

- Make sure you enable your computers wireless card and connect to the Vantage SSID. The Vantage SSID is the serial number of the MCU, for example, Vantage 2-12230.
- Start FARO Tracker Utilities.
- In the TRACKER UTILITIES dialog box, click the **Find Trackers** button.

- In the FIND TRACKERS dialog box, click the **Find Trackers** button.
- Write down the Serial Number, IP Address, and IP Mask.
- If necessary, select the serial number and click the TURN WIRELESS OFF button.

Wireless Reset

In certain situations the wireless transmitter in the MCU is on, but you cannot connect to the computer or the computer does not have a wireless receiver, you can reset the wireless transmitter and temporarily connect using the cross-wired ethernet cable. There is a wireless reset button inside the MCU and pressing it using a thin (0.05mm/0.002in) metal blade starts the reset.



Figure 5-7 MCU Reset Switch Location

On the right side of the MCU, locate the right set of ventilation slots. Insert the blade into the left side of the third ventilation slot from the bottom until you depress the reset switch. The Primary and Secondary Indicator Lights begin to flash when the switch is depressed.

MCU Quick Reset.

Use this procedure if the wireless is on, you cannot connect to the computer, and want to turn the wireless off.

- Press and hold the wireless reset button for 1-3 seconds. Notice the Primary and Secondary Indicator lights flashing. Release the wireless reset button.
- Connect cross-wired ethernet cable to the MCU and your computer.

- Start FARO Tracker Utilities and click the **Find Trackers...** button.
- Clear the MATCH IP ADDRESS OF THE TRACKER REACHABLE FROM PC check box.
- Click the **Find Trackers** button. Wait until the AVAILABLE TRACKERS window updates.
- Select the serial number and click the **Turn Wireless Off** button.
- Power off and power on the MCU. Notice the Notice the Primary and Secondary Indicator lights do not flash during the start up.
- Exit FARO Tracker Utilities.

Chapter 6: Understanding Measurement Accuracy

In order to determine the uncertainty associated with a particular measuring session, carefully estimate the contribution of errors from all identifiable sources. However, since the effects of some environmental factors (excess vibration, mounting stability, and temperature effects such as temperature gradients, air turbulence, or air pockets of different temperatures in the path of the laser beam, etc.) are difficult to quantify, good metrology practice requires that the effects of all sources of error be minimized or eliminated. If the effects of environmental errors are left completely uncontrolled, the accuracy of the measurements may degrade to such an extent that the entire measuring session has to be rejected. Whenever possible, measure your part in a location where environmental factors are closely controlled and kept stable.

Effects of Atmospheric Conditions

Atmospheric conditions can have multiple effects on Laser Tracker measurements. Temperature gradients, air turbulence, or air pockets of different temperatures in the path of the laser beam will affect the direction of the laser beam resulting in a loss of accuracy in both the angular and radial distance measurements. Typically, gradients, turbulence, or air pockets are always changing, so this accuracy loss is not always the same magnitude or even the same direction. This effect creates poor repeatability in addition to the accuracy loss. Increasing the number of samples per reading can sometimes improve the repeatability of measurements in these conditions, but it does not necessarily improve the accuracy of each measured reading. Avoid these errors by not measuring near heating and air conditioning ducts, doors that frequently open, or any other source of these temperature effects. Airflow in general is not the issue as an environment with high airflow of a uniform temperature can result in very good measurements. It is the regions where two different air masses of different temperatures that causes the laser beam to bend. Another method to managed the effect of non-uniform temperature is to use a fan to mix the air so there is no pockets of different air temperatures in the measurement area.

As the temperature, barometric pressure, and relative humidity of air change, so does the index of refraction. Knowing the air's index of refraction is critical for the accuracy of the radial distance measurements performed by the Laser Tracker's ADM system because these systems need to convert the waves of light being measured into a distance and the speed of light changes based on environmental conditions. The index of refraction cannot be calculated correctly

without accurate atmospheric condition values. The Laser Tracker system is equipped with weather sensors that measure the temperature, pressure, and humidity of the ambient air every five seconds. A 1 part per million change in the index of refraction, and the resulting radial distance measurements, occurs for a 3 mmHg change in pressure, a 1°C change in temperature, or a 40% change in relative humidity at 40°C. Because the air temperature has a significant effect on the index of refraction, the Laser Tracker's external air temperature sensor should be placed in air at the same temperature that the laser beam is traveling through and not inside a work cart, near heating or air conditioning ducts, or any other source of a thermal effect.

Environmental Conditions

Environmental effects such as excess vibration, mounting stability, and temperature can affect the accuracy and repeatability of the measurements. Eliminate these outside factors whenever possible.

Do not move heavy objects near the part before or during a measurement session. This may cause the floor to shift or move enough to disrupt measurement sessions. The magnitude of this effect depends largely on the weight of the object and the stability of the workshop floor foundations.

Support the part in the same manner for measurement as its intended function. This ensures that differential loading does not result in distortions in the part when it is put to use.

FARO recommends taking redundant readings for each measurement. Taking redundant readings provides a means of detecting gross errors or blunders, may reduce the environmental effects that you have not been able to eliminate, and provides better statistical sampling. For example, measure a planar surface with more than three readings.

Targets and Tooling

Regularly check the target nest and the SMR for metal filings or debris that may prevent the target from seating properly in the nest. Regularly inspect the tooling for ware, dings or dents that may cause the tooling not to contact the part or the SMR at the designed location. For the best results all tooling and SMRs should be part of the gage calibration system and checked for the proper dimensional values. Almost undetectable damage to tooling can greatly exceed the accuracy specifications of the Laser Tracker system and can lead to incorrect results of the measurement session.

Dimensional inaccuracies of target offsets are a frequent source of error during a measurement session. Before measuring, check the Probe settings in your measurement software to select any additional tooling to ensure the correct offset is being applied to the measurements. For more information see:

- CAM2 Measure 10 - See “Probes” on page 122.

Physical Changes in the Part or Stand

Regularly inspect the instrument stand and the part to make sure that both remain stable throughout measuring; any change to the position of the instrument stand and the part degrades the measurement accuracy. When possible the instrument stand should be on the same section of flooring as the part and having the legs span two or more sections of flooring should be avoided.

An often overlooked source of measurement error is temperature changes of the instrument stand. If the instrument stand was stored in an area with an ambient temperature different than where you are now measuring, then stand movement may be occurring as it acclimates to its new environmental condition.

Temperature changes in the environment during measuring can degrade accuracy by causing thermal expansion or contraction of the part. The magnitude of this effect depends on the material of the part, the size of the part, the magnitude of the temperature change and the rate the temperature changed. Monitor this by regularly checking reference nests set up on the part. FARO's CAM2 software, and most other inspection software, have methods to re-measure reference nests set up on the part and re-align while applying a scaling change to compensate for uniform thermal expansion or contraction in subsequent measurements. In some situations, this environmental change may change the Laser Tracker's angular accuracy, so you may need to run an Angular Accuracy check before re-aligning to the part.

Whenever possible, shield the Laser Tracker Measuring Head and the part from external heat sources. Radiant energy from the sun, hot lights, or space heaters during measurement can introduce non-uniform expansion in the measurement equipment or the part, degrading the measurement accuracy.

Angular Accuracy Checks

The Laser Tracker Measuring Head reads the azimuth and zenith angles and the distance to the target for each reading in a measurement. A kinematic model corrects the readings. The model has parameters for the laser beams four degrees of freedom (two rotational and two translational), and two parameters for the gimbal (axis offset and axis non-squareness).

Verify the system accuracy using the Angular Accuracy Checks. *For more information, see “Angular Accuracy Checks” on page 79.* These checks compare a point reading taken in front sight mode with one taken in back sight mode. The resulting deviation reports twice the worst-case error for a point measured at the range and position of the back sight reading.

Although the kinematic model is highly effective in minimizing measurement error, there are still many factors that are not accounted for by the model. Target quality, atmospheric induced errors, and thermal expansion are some of the errors not addressed by the model.

Positioning of the Laser Tracker

All Laser Tracker measurements consist of two angular measurements and one radial distance measurement. The angular measurement system and the radial measurement systems both have a specified maximum error. An additional source of error is known as the R0 parameter which is a radial offset. This is the error in the known distance from the Laser Tracker's origin to the SMR while it is sitting in the Tracker Mounted Reset (TMR), also known as the Home position. See Chapter 9: Product Specifications, for the Maximum Permissible Error (MPE) for these items as well as equations for calculating the Maximum Permissible Error for the distance between two points.

All Laser Tracker measurements contain all of these error sources. However, as shown in the information in Chapter 9: Product Specifications, it is possible that the distance between two points measured from one Laser Tracker position is more accurate than when measuring the distance between the same two points from a different Laser Tracker position. For example, a Laser Tracker measuring the length of a scale bar placed directly in line with the laser beam will be more accurate than the same scale bar placed horizontally of the Laser Tracker. This is because:

1. The maximum permissible error of the Laser Tracker's radial distance measurement system is lower than the maximum permissible error of the Laser Tracker's angular measurement system.
2. The maximum permissible error of both the Laser Tracker's angular measurement system and radial distance measurement system increase the further you move from the Laser Tracker.
3. The contribution of R0 error of the distance between two points measured from one Laser Tracker position is different than the same two points measured from a different Laser Tracker position.

While every measurement session and geometry is unique, you can sometimes optimize the overall accuracy of the measurement session by reducing the angular movement used in its physical measurement compared to the dimension of interest. For example, if the straightness of a rail is more critical than its height or length, then placing the Laser Tracker on the side of the rail so the radial measurement system is predominantly used to measure its straightness would typically produce more accurate measurements. If the length of the rail is more critical than its straightness, then placing the Laser Tracker the end of the rail so the radial measurement system is predominantly measuring its length would typically produce more accurate measurements. This is assuming that the Laser Tracker can be placed in these locations without introducing other sources of error such as floor vibration or air turbulence due to temperature gradients, etc.

Recommendations for Optimal Results

Errors associated with environmental conditions, targets or target tooling, movement or changes in the part or stand, etc. occur with most types of measurement equipment. However, these are some guidelines specific to the Laser Tracker that, when followed, result in improved measurement accuracy.

- Optimal results will always occur in an environment that does not have large temperature changes, temperature gradients, air movement, floor vibrations, etc. Steps to minimize the sources of these in the environment should be taken prior to beginning measurements.
- Let the Laser Tracker fully complete Thermal Stabilization in the Startup Checks. If this is skipped, a decrease in the Laser Tracker's accuracy will occur.

NOTE: In order for the FARO Laser Tracker Vantage to perform within the published specifications, you must allow Thermal Stabilization to complete or the Laser Tracker Measuring Head should be powered on and locked onto an SMR for 1 to 2 hours to warm-up as is typical of all Laser Tracker devices.

- Verify the Laser Tracker's accuracy prior to beginning measurements running the Quick Compensation routine. You should then run the Angular Accuracy Checks and Pointing Compensation routines if the Angular Accuracy Checks fails and CompIT recommends it.
- When measuring quickly after setup is more important than having the best accuracy, running the Quick Compensation or Pointing Compensation routines every 15 minutes after running the initial Quick Compensation routine is the best method to manage the warm-up cycle while measuring.

The Angular Accuracy Checks should be run after all compensations to confirm the changes to the compensation parameters, and to be sure that the Laser Tracker's accuracy meets the measurement job requirements.

- Quick Compensation is the fastest compensation and is acceptable where the best accuracy is not required. However, Pointing Compensation yields lower backsight error or improved Angular Accuracy results. Calculating the very best kinematic parameters is important for high accuracy applications especially at longer distances. For very high accuracy measurements and /or measurements at long distances, having a properly warmed-up Laser Tracker Measuring Head and running the Pointing Compensation routine is required.
- Periodically check for movement between the part and the Laser Tracker Measuring Head using common points attached to the part. If excessive movement is detected or if the ambient temperature has changed more than approximately 2.8° Celsius (5° Fahrenheit), use the **Move Device** command in CAM2 software, or the equivalent in other software, to realign to the part if movement has occurred. Perform this check even in environments where ambient temperature changes and vibration are kept to a minimum.
- Periodically reset the SMR to the Home position for very high accuracy measurements. This resets the ADM distance to the known distance to the center of the SMR in the Home position and can eliminate very small changes that can occur over time or temperature in the radial measurements. This is also known as Tracker Mounted Reset (TMR). These very small changes do not affect most applications but can affect very high accuracy measurements.
- By default, an individual reading of a measurement uses a sampling rate of 1000 samples per reading resulting in a total measurement time of 1 second. When using a scanning or dynamic method to collect readings, reduce the total measurement time by lowering the total number of samples per reading. Moving the SMR over a curved surface while taking 1000 samples per reading typically used for the static measurement, results in a single reading that is the average of the SMR movement over a 1 second time period. A typical scan setting would be to lower the samples per reading to 5 resulting in an individual measurement time span of 5 milliseconds. Moving the SMR over a curved surface with this setting will result in a series of multiple readings that are identical to the path the SMR traveled around the curve. Use the **Hardware Configuration** command in the measurement software to change this setting. See "*Hardware Configuration*" on page 121.
- Do not turn the Laser Tracker Measuring Head's motors off during breaks or shift changes. Turning the motors off for long periods of time can result in a

slight change in the Laser Tracker Measuring Head's internal operating temperature away from its stabilized condition. This can degrade accuracy in the measurements taken soon after turning the motors back on. Leaving the motors on will prevent this from occurring. Leaving the motors on will not harm the Laser Tracker Measuring Head.

- Do not cover the Laser Tracker Measuring Head while it is turned on. Only use the Laser Tracker Measuring Head's dust cover when it is turned off. Using the dust cover while the system is turned on will not allow the Laser Tracker Measuring Head to properly stabilize to the environments current ambient temperature. This can degrade accuracy in the measurements taken soon after removing the cover. If the environment is very dirty and you are concerned about dust on the embedded targets, you can track to the left or right side of the Laser Tracker Measuring Head to rotate the Azimuth axis so that it covers these targets.

Chapter 7: Care of the FARO Laser Tracker Vantage

Use care in handling the Vantage system, especially while moving it from and one place to another; there are no user replaceable parts.

Optical Target Care

Optical Targets, such as the spherically mounted retroreflector (SMR), are an important part of the Vantage. Handle SMRs with great care to ensure accuracy and longevity.

Target care includes:

- Never touching the optical surfaces of the target.
- Never dropping the target.
- Keeping the target free of dust and moisture by storing it in the case when not in use.
- Cleaning the target *only* when there are problems acquiring the target or the Operational Checks indicates cleaning is necessary.
- Always using the proper cleaning materials and procedure when cleaning is required.

If the Vantage does not lock onto the target, use the Operational Checks command to check your SMR. If the Return Power value is “GOOD” your SMR does not need cleaning.

CAUTION: Unnecessary cleaning will degrade the reflective surface of the SMR and can cause damage to the coatings on silver surfaces that will eventually destroy the SMR. Only clean SMRs when required for good measurement and accuracy performance, not based on cosmetic conditions.

Cleaning the Optical Targets

In many cases, the optical surfaces of the target are simply dusty and just require cleaning with compressed air from a can.

CAUTION: Do not clean with compressed air available from a hose in a workshop - the air is seldom clean and may coat the SMR with oil or some other contaminant.

- Spray the air away from SMR for a few seconds before spraying it onto the optical surfaces to remove any propellant in the can from the air nozzle. This prevents the propellant from being sprayed onto the SMR's optical surfaces.

Always hold the can upright and never shake the can when spraying compressed air.

If the target is still not functional after blowing off any dust, use the following target specific procedures.

CAUTION: Never use a dry cotton swab or tissue to clean the optical surfaces because these will scratch the optical surfaces. Cleaning with any improper chemicals will destroy the reflective surface.

1. Breathe on the optical surfaces. The moisture in your breath will form a layer of condensation on the optical surfaces.
2. While condensation is still on the glass surface, gently slide a cotton swab in one direction while rotating it in the opposite direction. Use very little pressure, do not push the cotton swab onto the surface. Use one cotton swab for each pass and then discard it. You may need several swabs to clean the optical surfaces thoroughly. Using a cotton swab more than one time can cause debris to scratch the coatings and on silver SMRs, a scratch can lead to oxidation under the coatings and destroy the SMR.
3. If this does not successfully remove the residue, clean the optical surfaces with Optima Grade acetone for oil based residue or denatured alcohol for water based residue.
4. Moisten a clean cotton swab with solvent.
5. Gently slide the cotton swab in one direction while rotating it in the opposite direction. Use very little pressure, do not push the cotton swab onto the surface. Use one cotton swab for each pass and then discard it. You may need several swabs to clean the optical surfaces thoroughly.
6. Remove any remaining cotton dust with canned compressed air.

Cleaning the Laser Trackers Optics

The Laser Tracker Measuring Head's aperture window and the embedded target covers may need occasional cleaning.

- Remove any dust from the window using canned compressed air. Before spraying the air onto the window, spray the canned air away from the window while holding the can upright to remove any propellant from the nozzle.
- If more cleaning is necessary, use water vapor and a clean cotton swab in the same manner as the SMRs (above). If water vapor does not successfully remove the residue, use denatured alcohol.

Storage

When storing for long periods of time, pack the Laser Tracker System in its shipping cases to protect it from environmental hazards, dust, dirt, etc. Store the system in an environment between -20°C and 70°C where it will not be subject to rapid temperature changes, extreme environmental conditions, or heavy vibrations. The storage cases are not waterproof, so do not store the system outside or in an environment that does not remain dry at all times.

Transportation

When transporting a Laser Tracker Measuring Head that is mounted on a heavy duty stand with wheels around a shop floor, you do not need to remove it from the stand. Although, before moving, lower the stands wheels and vertical extension tube. While in motion, avoid any divots or large gaps in the floor.

When transporting a Laser Tracker Measuring Head that is mounted on a portable tripod without wheels around a shop floor, remove it from the tripod before moving. After the tripod is in the new location, mount the Laser Tracker Measuring Head on top of the portable tripod.

When transporting the Laser Tracker System long distances or between facilities, pack everything in the portable cases and pack the portable cases in the shipping cases. Always use straps to secure the shipping cases to a pallet when using a forklift, and gently lift and lower the pallet.

CAUTION: *Do Not* ship these cases stacked and locked together. Only stack and lock the shipping cases together when using the casters on the bottom shipping case for local transportation.

Ingress Protection (IP) Rating

The Laser Tracker Measuring Head has an IP rating of 52 as defined in International Standard IEC 60529. This two digit rating is:

- First Digit (Solid Particle Protection): 5 - Dust Protected. Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the satisfactory operation of the equipment; complete protection against contact.
- Second Digit (Water Protection): 2 - Dripping water when tilted up to 15°. Vertically dripping water shall have no harmful effect when the enclosure is tilted at an angle up to 15° from its normal position.

The Master Control Unit (MCU) has an IP rating of:

- First Digit (Solid Particle Protection): 4 - Protection of objects >1 mm. Effective against most wires, screws, etc.
- Second Digit (Water Protection): 0 - Not protected.

With the MCU Filter Kit installed, the MCU has an IP rating of:

- First Digit (Solid Particle Protection): 5 - Dust Protected. Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the satisfactory operation of the equipment; complete protection against contact.
- Second Digit (Water Protection): 0 - Not protected.

With the MCU Filter Kit and MCU Cover installed, the MCU has an IP rating of:

- First Digit (Solid Particle Protection): 5 - Dust Protected. Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the satisfactory operation of the equipment; complete protection against contact.
- Second Digit (Water Protection): 2 - Dripping water when tilted up to 15°. Vertically dripping water shall have no harmful effect when the enclosure is tilted at an angle up to 15° from its normal position.

CAUTION: The Vantage system IP rating provides water protection equivalent to rainfall of 3mm per minute for 10 minutes. It does not provide protection from large volumes of water for extended periods of time, water spraying on the Laser Tracker system at high pressures. Water protection is provided when the Laser Tracker Measuring Head is in its normal, or upright, position.

Chapter 8: Getting Help

This chapter describes the different resource tools that you should use to get help with your Vantage system. These include electronic Help files, printed documentation, and the FARO Customer Service Department.

Online Help

FARO CAM2 Measure is the primary software product for use with the Vantage and contains a help file that covers an extensive range of topics.

Documentation

This User Manual covers topics associated with the use of the Vantage main hardware components. This manual also includes detailed procedures for performing diagnostic checks and completing various calibration and compensation routines.

See “*Operational Checks*” on page 69 and “*FARO CompIT*” on page 77.

Other FARO Publications include:

- FARO’s CAM2 Measure user manual which covers the use of the inspection software.
- The *FARO Laser Tracker Accessories Manual* which covers the setup and operation of the optional accessories for the FARO Laser Tracker system.

FARO Customer Service

FARO is proud to provide its customers with the best support in the industry. Our commitment to servicing our customers needs is evident in our products, services, and customer satisfaction. The following section explains how you can contact FARO Customer Service with any technical questions.

How to Contact FARO

To aid in our responsiveness, FARO asks that customers use one of the following methods to contact the Help desk with technical questions:

Internet

Visit the FARO WEB site at www.faro.com and enter the Support Center found under Customer Care.

Electronic Communication

FARO Laser Tracker Vantage
April 2016

Phone, Fax or E-Mail. See *“Technical Support”* on page 139.

Mailing Address

FARO Technologies, Inc.
250 Technology Park
Lake Mary, FL 32746

International Mailing Addresses

FARO Europe GmbH & Co. KG
Lingwiesenstrasse 11
D-70825 Korntal-Münchingen
Germany

FARO (Shanghai) Co., Ltd
1/F, Building No. 2,
Juxin Information Technology Park
188 Pingfu Road, Xuhui District
Shanghai 200231, China

FARO Japan, Inc
716 Kumada, Nagakute-shi,
Aichi 480-1144, Japan

FARO Singapore Pte Ltd
No.3, Changi South Street 2,
#01-01 Xilin Districentre Building B,
Singapore 486548

Chapter 9: Product Specifications

This chapter contains the Vantage technical specifications. For other FARO Laser Tracker models, please consult the original User Manual that shipped with your FARO Laser Tracker or contact FARO Customer Service.

General Specifications and Rated Conditions

SIZE

| | |
|------------------------------|-----------------------------|
| Laser Tracker Measuring Head | 224(W) x 416(H) mm |
| Master Control Unit | 290(L) x 158(D) x 214(H) mm |

WEIGHT

| | |
|------------------------------|---------|
| Laser Tracker Measuring Head | 12.6 kg |
|------------------------------|---------|

RATED CONDITIONS

| | |
|--------------------------------------|---|
| <i>Measurement Envelope Distance</i> | 80m (262.5ft) with select targets 60m (196.9ft) Standard 1.5" SMR 40m (131.2ft) Standard 7/8" SMR 30m (98.4ft) Standard 1/2" SMR |
| <i>Range of horizontal angle</i> | 360 degrees - infinite rotation |
| <i>Range of vertical angle</i> | 130 degrees (+77.9/-52.1) |
| <i>Temperature Range</i> | |
| Operating | Min -15°C, Max 50°C Min 5°F, Max 122°F |
| <i>Humidity</i> | |
| Operating | Min 0% RH, Max 95% RH |
| <i>Barometric Pressure Range</i> | |
| Operating | Min 225.50 mmHG, Max 825.07 mmHG Min 8.878 inHG, Max 32.483 inHG |
| <i>Elevation</i> | |
| Operating | -700m to 9000m (-2,297ft to 29,527ft) |

| | |
|--|--|
| <i>Ambient Light</i> | Direct exposure to sunlight or flash lamps may compromise performance. |
| <i>Electrical</i> | |
| Voltage | 100 - 250 VAC \pm 10% |
| Current | 5A (US), 2.5A (EU) |
| Frequency | 50/60 Hz |
| Surg | 1000 V common, 500 V differential, 1.25/50 μ s waveform |
| Sag | 70% Nominal Voltage, 0.5s, 40% Nominal Voltage, 5.0s |
| Max Transient Voltages and Duration | 1000 V common, 500v differential, 5/50 ns, 1 min waveform |
| <i>Probe Type</i> | |
| Diameter | 1.5 in (38.1 mm), 7/8 in (22.225 mm), or 1/2 in (12.7 mm) |
| Reflector Type | Spherically Mounted Retroreflector (SMR) |
| <i>Sampling Strategy</i> | |
| Acquisition time | 1 sec |
| Frequency | 1000 points/sec |

LIMITING CONDITIONS

| | |
|----------------------------------|---|
| <i>Storage Temperature Range</i> | Min -20°C, Max 70°C Min -4°F, Max 158°F |
| <i>Humidity Range</i> | Min 0% RH, Max 100% RH |
| <i>Barometric Pressure Range</i> | 7500 mmHg overpressure 295.276 inHG overpressure |

Spherically Mounted Retroreflector (SMR)

The accuracy of measurements made with the Vantage system depend on characteristics of the Spherically Mounted Retroreflector (SMR) such as:

- Ball diameter
- Vertex position
- Flatness of the optics
- Dihedral angle errors
- Reflectivity of the optics

The specifications for the Vantage system are valid when using SMRs certified by FARO. Mishandling of the SMR may change one or more of these characteristics and diminish the accuracy of the measurements taken with the Vantage. See “*Optical Target Care*” on page 55.

Measurement Specifications

Angular Encoders (transverse)

Horizontal Envelope: $\pm 360^\circ$ - infinite rotation
Vertical Envelope: $+77.9^\circ$ to -52.1° - infinite rotation
Maximum Angular Measurement Velocity: $180^\circ/\text{sec}$.
Maximum Angular Acceleration: $860^\circ/\text{sec}^2$ ($15 \text{ rads}/\text{sec}^2$)
Maximum Angular velocity: $180^\circ/\text{sec}$ ($\pi \text{ rads}/\text{sec}^2$)

ADM (radial)

Sample Rate: 16,000 samples/second
Resolution: $0.5 \mu\text{m}$
Maximum Radial Acceleration: $30\text{m}/\text{sec}^2$
Maximum Radial Velocity: $> 25\text{m}/\text{s}$

Working Range

Minimum Working Range: 0 m
Maximum Working Range:
80m with select targets
60m Standard 1.5” SMR
40m Standard 7/8” SMR
30m Standard 1/2” SMR

Level

Accuracy +/- 2 arc seconds

MultiView Cameras

Field of View: 30°

Data Acquisition

System Sample Rate 1,000 samples per second

Point Acquisition Rate 350 points per second

Accuracy Specification and Formulas

The following discussion presents details on the accuracy for the Vantage per the ASME B89.4.19 - 2006 Standard. Accuracy is expressed as Maximum Permissible Error (MPE). Typical performance is half the MPE values.

See Table 9-1 for the performance specifications for the Vantage. Measurement accuracy is affected not only by Laser Tracker System performance but also by the variation in air temperature, as quantified in Table 9-2.

| Laser Tracker Measuring Head Subsystem | Symbol | Maximum Permissible Error | |
|--|-----------|--------------------------------|-----|
| Absolute Distance Meter (ADM) | e_{ADM} | $16\mu m + L \cdot 0.8\mu m/m$ | (1) |
| R0 parameter (R0) | e_{R0} | $16\mu m$ | (2) |
| Transverse | e_r | $20\mu m + L \cdot 5\mu m/m$ | (3) |

Table 9-1

| Measurement Type | Symbol | Error | |
|------------------|-------------|--|-----|
| Radial | E_{TEMPR} | $L \cdot (\Delta T_{AVE}/^{\circ}C) \cdot (1\mu m/m)$ | (4) |
| Transverse | E_{TEMPT} | $0.5 \cdot (L^2 \partial T/\partial x)_{EFF} \cdot (1/^{\circ}C) \cdot (1\mu m/m)$ | (5) |

Table 9-2

The geometrical arrangement of a Laser Tracker Measuring Head that measures the coordinates of points 1 and 2 is shown in Figure 9-1. From these coordinates, the length d is determined. The maximum permissible error (MPE) in this length measurement is the maximum error permitted by the performance verification

tests. The MPE of measured length d is calculated using Equation (7) below. In this equation, the quantities that contain the subscripts R1 or R2 refer to either the ADM or optional IFM specifications in Table 9-1, depending on whether the ADM or optional IFM is used.

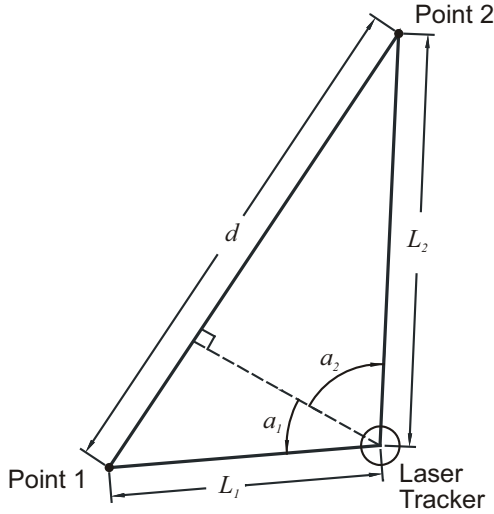


Figure 9-1 Laser Tracker Measuring Head Geometry

$$MPE_d = \left(e_{R1}^2 \sin^2 a_1 + e_{R2}^2 \sin^2 a_2 + e_{R0}^2 (\sin a_1 + \sin a_2)^2 + e_{T1}^2 \cos^2 a_1 + e_{T2}^2 \cos^2 a_2 + E_{TEMPR1}^2 \sin^2 a_1 + E_{TEMPR2}^2 \sin^2 a_2 + E_{TEMPT1}^2 \cos^2 a_1 + E_{TEMPT2}^2 \cos^2 a_2 \right)^{\frac{1}{2}} \quad (7)$$

Figure 9-2

The angles a_1 and a_2 are positive in the directions shown in Figure 9-1 and negative in the opposite directions. The quantities e_{R1} , e_{R2} , e_{R0} , e_{T1} , and e_{T2} are calculated using Equations (1) - (3). The subscript 1 refers to path 1 and the subscript 2 refers to path 2. So, for example, $e_{T1} = 36\mu m + L_1 \cdot 6\mu m/m$. The quantities E_{TEMPR1} , E_{TEMPR2} , E_{TEMPT1} and E_{TEMPT2} are calculated using Equations (4) and (5). The quantity ΔT_{AVE} in Equation (4) is the average temperature of the air through which the laser beam passes minus the temperature of the air at the air temperature sensor. For a laser beam that travels through path 2, $E_{TEMPR2} = L_2 \cdot (\Delta T_{AVE2}/^{\circ}C) \cdot (1\mu m/m)$. The quantity $(\partial T/\partial x)_{EFF}$ in Equation (5) is the maximum effective thermal gradient in the direction

transverse (perpendicular) to the path of the laser beam. Transverse temperature gradient is defined as the number of degrees of temperature change per unit distance in the direction transverse to the laser path. For path 1,

$E_{TEMP1} = 0.5 \cdot L_1^2 (\partial T / \partial x)_{EFF1} \cdot (1/^\circ C) \cdot (1 \mu m / m)$. In ordinary factory environments, the last four terms in Equation (6) - the thermal terms - can be ignored. In the testing of Laser Tracker Systems at the FARO factories and service centers, these thermal terms in Equation (6) are omitted in the calculation of MPE.

A special case is the outside buck-in measurement in which the Laser Tracker Measuring Head is aligned with points 1 and 2 as shown in Figure 9-3.

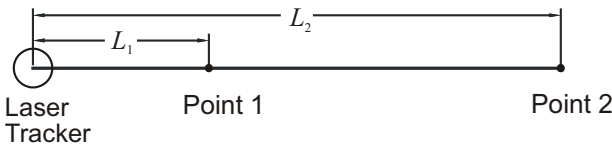


Figure 9-3 Laser Tracker Measuring Head Buck-In Geometry

Point 1 establishes the reference for the measurement, much as the home position establishes the reference point for many other measurements. Also, in this case, the air temperature of the beam path between the Laser Tracker Measuring Head and point 1 is the same for both measurements. Under these conditions, the two coordinate measurements are correlated, permitting Equation (6) to be rewritten as:

$$MPE_d = e_{R12} + E_{TEMPR12} \tag{7}$$

Here, the quantity e_{R12} refers to the specifications in Table 9-1. In Equations (1) and (2), the length is equal to the distance between the points; in other words, $L = L_2 - L_1$. Also, the quantity

$E_{TEMPR12} = (L_2 - L_1) \cdot (\Delta T_{AVE12} / ^\circ C) \cdot (1 \mu m / m)$, where ΔT_{AVE12} is the average temperature of the air between points 1 and 2 minus the temperature of the air at the air temperature sensor.

Another special case is that of the two-face measurement. In this measurement, the coordinates of a point are first measured in the usual mode, referred to as front-sight mode, and then in the backsight mode. To put the Laser Tracker Measuring Head in backsight mode, the azimuth axis is rotated by 180 degrees and then flipped about the zenith axis to point the laser beam back at the target. The transverse distance between the front-sight and backsight coordinates is the backsight error. The two-face test is a challenging test of performance because

most of the Laser Tracker Measuring Head transverse errors are doubled. The two-face MPE is:

$$MPE_{two-face} = 2e_{R1} \quad (8)$$

The following tables list MPE tolerances for scale bar and outside buck-in tests based on the B89.4.19 - 2006 Standard (equations described above). Ranges in the tables are taken directly from the B89.4.19 specification and the values are taken from a sample FARO Laser Tracker Vantage B89 report available for review from FARO Customer Support.

**Nominal B89.4.19 MPE Values for
 2.3 Meter Scale Bar**

| Scale Bar Measurements | MPE (ADM, micrometers) |
|-------------------------------|-----------------------------------|
| Horizontal (0.2 m) | 39.8 |
| Horizontal (2.8 m) | 48.4 |
| Horizontal (6.2 m) | 70.7 |
| Vertical (2.8 m) | 48.6 |
| Vertical (6.2 m) | 70.7 |
| Right-Diagonal (2.8 m) | 48.5 |
| Right-Diagonal (6.2 m) | 70.7 |
| Left-Diagonal (2.8 m) | 48.5 |
| Left-Diagonal (6.2 m) | 70.7 |
| Two-Face (0.4 - 0.5 m)* | 52.4, 46.7, 43.7 |
| Two-Face (2.8 m)* | 70.3, 70.2, 67.9 |
| Two-Face (6.2 m)* | 101.1, 101.1, 100 |

* For high, medium and low points

Table 9-3

| Outside Buck-In Measurements | MPE (ADM, micrometers) |
|-------------------------------------|-----------------------------------|
| Ranging Test (6 m) | 20.8 |
| Ranging Test (12.5 m) | 25.8 |
| Ranging Test (19 m) | 31.3 |
| Ranging Test (25 m) | 35.7 |

Table 9-4

Chapter 10: Operational Checks

This chapter describes the Operational Checks for the Vantage. These checks use commands found in FARO CAM2 Measure.

NOTE: The Vantage is only compatible with CAM2 Measure v10.1 and later.

The Operational Checks determine the operating condition of the Laser Tracker Measuring Head as well as verifying that environmental factors such as air movement and vibration will not degrade measurement accuracy.

References

Vantage Assembly Instructions (Part Number C-RSR-06086-000)

Chapter 11: FARO CompIT. See “FARO CompIT” on page 77.

Equipment

1. Vantage and support equipment
2. Spherically Mounted Retroreflector (SMR)
3. Calibration Tripod, or nest, to hold the SMR securely at the reference position

When to Perform

Run the Operational Checks to ensure that the Laser Tracker System is operating/performing at the expected level of stability and repeatability in its current environment.

NOTE: If you move the system to a new operating environment, you should always run the Operational Checks.

Preparation

Set up, supply power to, and start the Laser Tracker System. *For more information, see “Setting up the FARO Laser Tracker Vantage” on page 27.*

NOTE: Powering down the system is not necessary at the end of the day; restarting is only necessary just after powering up.

Start your computer and the CAM2 Measure software.

Procedure

The following procedures cover the Operational Checks of the Vantage. In the CAM2 Measure software, open the OPERATIONAL CHECKS dialog box:

- On the **Devices** tab, select Hardware Configuration and in the FARO DEVICE CONTROL panel, click the **Environment Check** button. You can also press the **P** hot key to show the DEVICE CONTROL panel.

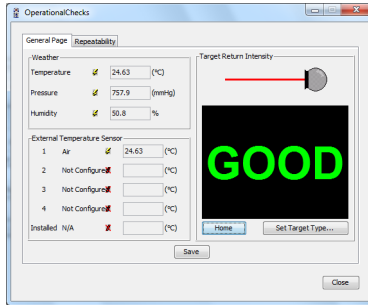


Figure 10-1 Operational Checks dialog box

General Page

View the Weather information and verify the SMR Return Power on the **General Page** tab of the OPERATIONAL CHECKS dialog box.

Use the **Save** and **Save As** buttons to save the test results to an ASCII text file.

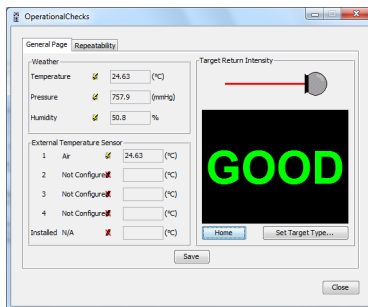


Figure 10-2 General Page of the Operational Checks

Weather

View the temperature, pressure, and humidity of the measuring environment. An icon indicates the source of the reading:

- Lightning Bolt - the reading originates from the Laser Tracker Measuring Head's internal sensors.
- Pencil - the reading has been manually entered.

NOTE: Use the Set Weather Configuration on the TrackerPad to manually enter the temperature, pressure, and humidity of the measuring environment. See “Set Weather Configuration” on page 128.

Target Return Intensity

The Target Return Intensity is the measure of the laser intensity as it returns to the Laser Tracker Measuring Head from an SMR. Intensity appears as:

- Good
- Marginal
- No Target

NOTE: A dirty SMR is the most common cause for a Marginal Target Return Intensity. If the SMR is very dirty, it may even read No Target. For more information, see “Optical Target Care” on page 55.

To check the SMR Return Power:

1. Choose the **Set Target Type...** button and select your SMR. Click **OK** to continue.

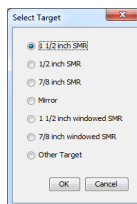


Figure 10-3 Set Target Type

- Place the SMR at the Home position on the Laser Tracker Measuring Head and click the **Home** button.

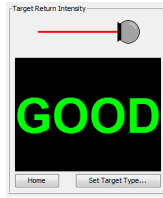


Figure 10-4 Target Return Intensity

Repeatability

The repeatability of measurements taken with the Vantage depends on the mounting of the Laser Tracker Measuring Head, the stability of the SMR, and environment factors such as air flow, temperature changes, vibration, etc. The Repeatability Page contains tests to ensure the Laser Tracker Measuring Head is consistent in its measurements in the current environment.

Choose the **Repeatability** tab of the OPERATIONAL CHECKS dialog box to start the Repeatability Checks.

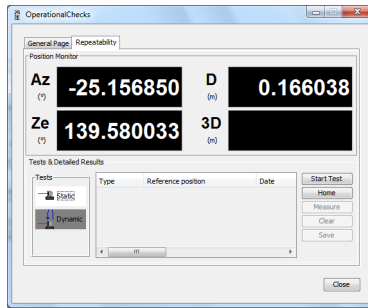



Figure 10-5 Repeatability

- The POSITION MONITOR section shows the real time position of the target expressed in the unit's spherical coordinate system: Azimuth angle (Az), Zenith angle (Ze), and Radial distance (D). The “dT” value shows the last measurement result.
- The TESTS section contain buttons to activate one of the three repeatability tests.
 - Use The **Start Test** and **Measure** buttons to carry-out the specific tests, and the **Home** button to reset the laser should a beam break occur.

- The TESTS & DETAILED RESULTS section shows the results of each test in detail. Use the **Clear** button to remove any test results.
- Use the **Save** and **Save As** buttons to save the test results to an ASCII text file.

Static Repeatability

The Static Repeatability check determines whether the Laser Tracker System can repeat the measured position of the SMR in a fixed position. The SMR remains at the reference position and does not move at all during the test. This check is critical for determining whether the Laser Tracker Measuring Head, part, and drift points are stable in the current environment.

1. Place the SMR in the Tracker Mounted Reset (TMR) or Home position.
2. From the **Repeatability** tab of the OPERATIONAL CHECKS dialog box, click the **Home** button to reset the laser.
3. Position the tripod or use an available nest approximately six (6) meters from the Laser Tracker Measuring Head. Angular position is not critical to this check. Use a control point on the part if the position is approximately six (6) meters from the Laser Tracker Measuring Head.
4. Remove the SMR from the home position and track to the reference position.
5. Select the  **Static** button and click on **Start Test**.
 - Enter a time delay between measurements, or use the default, and click **OK**.

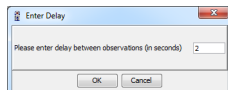


Figure 10-6 Enter Delay

- The Laser Tracker Measuring Head first measures the reference position, then after the time delay, measures the reference position again. Allow it to collect about ten (10) measurements.
6. Click **Stop Test** and review the results.
 - Look at the “Total” values in the TEST RESULTS section. The total error should be less than 0.025mm.
 7. If the total error is greater than 0.025mm, repeat this check at two other locations.

NOTE: If the total error is consistently high, check the stability of the Laser Tracker Measuring Head, mandrel, stand and the tripod/nest, and eliminate


any possible causes of air movement in the laser beams path before repeating the Static Repeatability Test. If the Static Repeatability Test continues to fail, contact FARO Customer Service.

Dynamic Repeatability

This check determines whether the Laser Tracker Measuring Head can repeat the measured position of the SMR at multiple positions throughout the measurement volume. This check is critical for determining whether the Laser Tracker Measuring Head, part, and drift points are stable while measuring with the SMR.

1. Place the SMR in the Tracker Mounted Reset (TMR) or Home position.
2. From the **Repeatability** tab of the OPERATIONAL CHECKS dialog box, click the **Home** button to reset the laser.
3. Use an available monument/nest affixed to a stable stand or on the measurement object as the reference position approximately six (6) meters from the Laser Tracker Measuring Head. Use a control point on the part if the position is approximately six (6) meters from the Laser Tracker Measuring Head.

NOTE: The calibration tripod supplied with the Vantage is NOT a suitable stand to use for this test.

4. Remove the SMR from the TMR and track to the reference position.
5. Select the  **Dynamic** button and click on **Start Test**.
 - The Laser Tracker Measuring Head first measures the reference position. Then, track the SMR around the measurement volume.
6. Return the SMR to the Reference position and click **Measure**.
7. Click **Stop Test** and review the results.
 - Look at the “Total” values in the TEST & DETAILED RESULTS section. The total error should be less than 0.025mm.
8. If the total error is greater than 0.025mm, repeat this check at two other locations.

NOTE: If the total error is consistently high, check the stability of the Laser Tracker Measuring Head, mandrel, stand and the tripod/nest, and eliminate any possible causes of air movement in the laser beams path before repeating the Static Repeatability Test. If the Static Repeatability Test continues to fail, contact FARO Customer Service.

Following the Checks

Your Laser Tracker System is now ready to perform repeatable measurements. In addition to these Operational Checks, always complete Quick Compensation and Angular Accuracy Checks prior to any measurement session to verify the accuracy of the system. See “*Quick Compensation*” on page 87, and “*Angular Accuracy Checks*” on page 79.

Chapter 11: FARO CompIT

This chapter is a reference guide for FARO CompIT. Before continuing, you must have a working knowledge of the Vantage System and FARO CAM2 Measure or FARO Tracker Utilities.

NOTE: The Vantage is only compatible with CAM2 Measure v10.1 and later, and FARO Tracker Utilities v3.0 and later.

The FARO CompIT software provides interim tests that allow for quick assessment of the system's pointing accuracy, ADM accuracy and precision level accuracy. It also provides compensation routines to adjust parameters that compensate the Laser Tracker Measuring Head's pointing accuracy. During all tests and compensations, CompIT will compare the results to the Maximum Permissible Error (MPE) of the Vantage per the ASME B89.4.19 Standard as defined in Chapter 9: Product Specifications. *For more information, see "Product Specifications" on page 61.*

Getting Started

Prior to running any test or compensations in FARO CompIT, set up, power up and start the Vantage. *See "Setting up the FARO Laser Tracker Vantage" on page 27.*

After the Vantage is properly set up, you can start FARO CompIT from the CAM2 Measure ribbon menu or from the Windows Start Menu.

CAM2 Measure



In CAM2 Measure, select **Hardware Configuration** from the **Devices** tab to show the DEVICE CONTROL panel. You can also press the **P** hot key to show the DEVICE CONTROL panel.

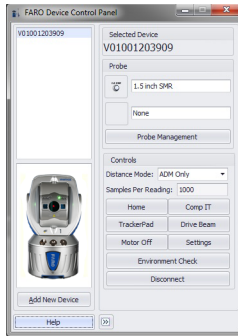


Figure 11-1 Device Control Panel

- Start the FARO CompIT program by pressing the CompIT button.

Windows Menu

CompIT is also accessible directly from the Windows Start menu by opening the FARO Tracker Utilities program, connecting to the Vantage, and clicking the CompIT button.

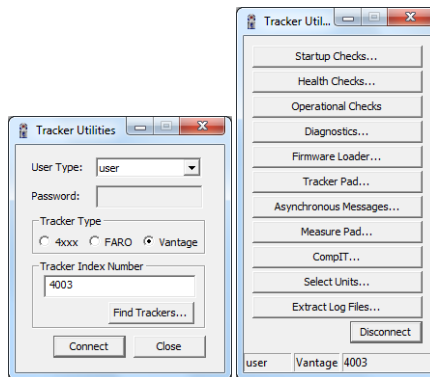


Figure 11-2 FARO Tracker Utilities

- To connect to the Vantage in FARO Tracker Utilities, either enter the IP address or enter its Index number (last 4 digits of the Laser Tracker Measuring Head's serial number).

Standard Tab

Clicking the CompIT button displays the CompIT dialog box.

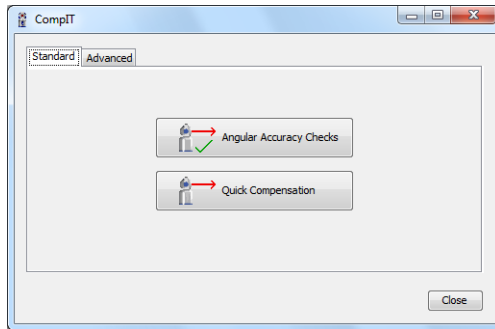


Figure 11-3 FARO CompIT dialog box

The Standard tab of the CompIT dialog box contains the two most frequently used functions: Angular Accuracy Checks and Quick Compensation.

Angular Accuracy Checks starts the Angular Accuracy test. See “*Angular Accuracy Checks*” on page 79.

Quick Compensation starts the Quick Compensation routine. See “*Quick Compensation*” on page 87.

Angular Accuracy Checks

Run this check after Startup Checks, before each measurement session, or if the temperature has changed more than approximately 2.8° Celsius (5° Fahrenheit). The Angular Accuracy Check verifies the system's accuracy during the course of a measurement session with minimal disruption. The CompIT Angular Accuracy Check measures the SMR in both front sight and backsight, and calculates the difference between the angular component of these two measurements, or the Backsight Error. The Angular Accuracy Check can collect backsight deviations anywhere in the measurement volume.

The Angular Accuracy checks compares the measured error to the Vantage's Maximum Permissible Error (MPE) based on your Vantage's specifications per the ASME B89.4.19 Standard. If the measured error is greater than the MPE, CompIT recommends a Quick Compensation.

Equipment

The Angular Accuracy Checks require a 1.5" Spherically Mounted Retroreflector (SMR) and stable nests to place hold the SMR. You can use either the Calibration Tripod or heavy duty nests attached to your part. If the nests are not stable during the duration of the measurement, the Angular Accuracy test may not be able to finish or its results can be poor.

Procedure

1. In the CompIT dialog box, click the **Angular Accuracy Checks** button. The SELECT MODE dialog box appears with two options:

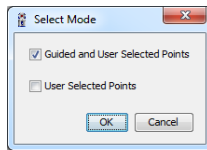


Figure 11-4 Select Mode dialog box

- **GUIDED AND USER SELECTED POINTS** first measures the Angular Accuracy at three specific locations recommended by CompIT with the option to measure additional locations after.
- **USER SELECTED POINTS** measures the Angular Accuracy at any location you choose. When using this option, you must use a minimum of three locations. The points should be at multiple distances and should cover the measurement volume of your part or tool.

2. After selecting a mode, the measurement screen appears:
 - Place the SMR in the Tracker Mounted Reset (TMR) or Home position.
Allow the Vantage to measure the TMR position.



Figure 11-5 Guided and User Selected Points - Home

3. After the Vantage automatically measures the Home position, track the SMR on the tripod to the desired location.

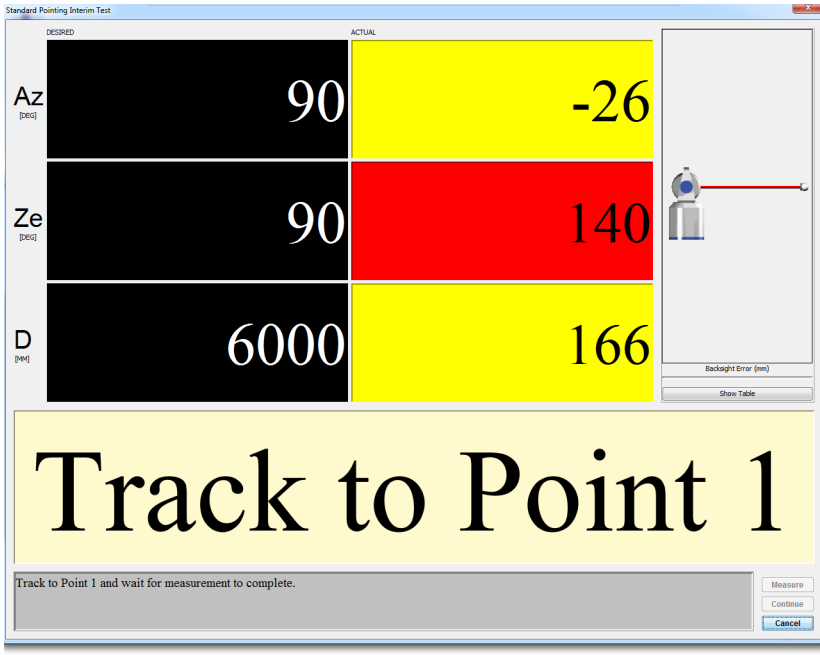


Figure 11-6 Guided and User Selected Points - Track to Point 1

- **DESIRED** value: When measuring Guided Points, these are the target values for Azimuth, Zenith and the Radial Distance. When measuring User Selected Points, the value is an *.
- **ACTUAL** value: The current Azimuth, Zenith, and Radial Distance values of the SMR. When all of the values are green, the system waits five (5) seconds for stability before measuring the SMR. When measuring User Selected Points, the values will always be green. When measuring Guided Points, the values switch to green when the SMR is

in an acceptable zone around the desired values. The Radial distance value switches to red if the SMR is beyond its desired value.

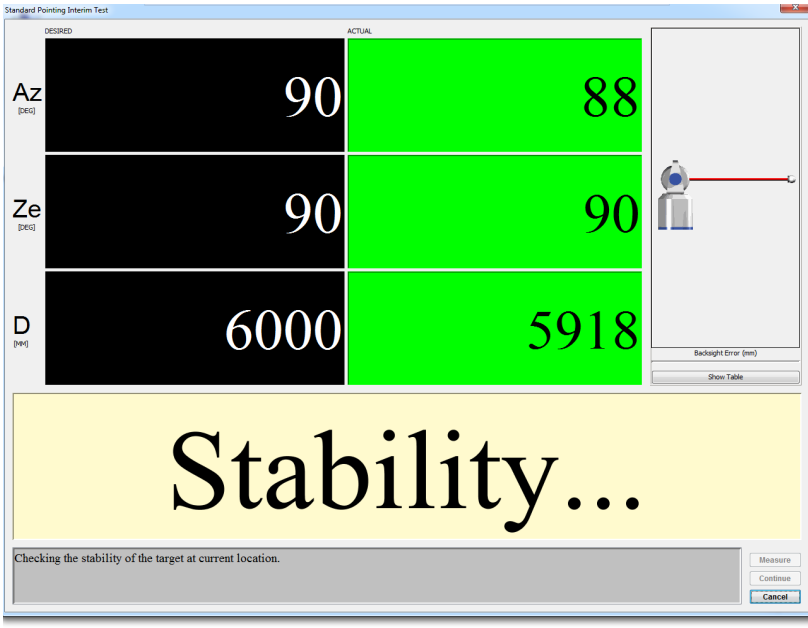


Figure 11-7 Stability

If the SMR does not stabilize within 60 seconds, an error message appears. Check the stability of the SMR and the Laser Tracker Measuring Head before trying again.

NOTE: If the Laser Tracker Measuring Head and SMR are mounted properly and the measurement still does not stabilize or takes longer than normal, please check for airflow or other environmental issues.

When the measurement is complete, the backsight error shows on the left side of the screen. After taking multiple measurements, the **Show Table** button can be used to show a list of any previous backsight errors.

NOTE: You can change the stability delay by clicking the Customize button in the Advanced tab of the CompIT dialog box. See “General” on page 118. You can disable the Auto Measure function by clicking the Settings button in the Advanced tab of the CompIT dialog box. See “Settings” on page 117. When Auto Measure is disabled, take measurements by clicking the Measure button.

4. When the backsight measurements at the first location are complete, move the SMR to the second location. Track the SMR to the next location and wait for stability.

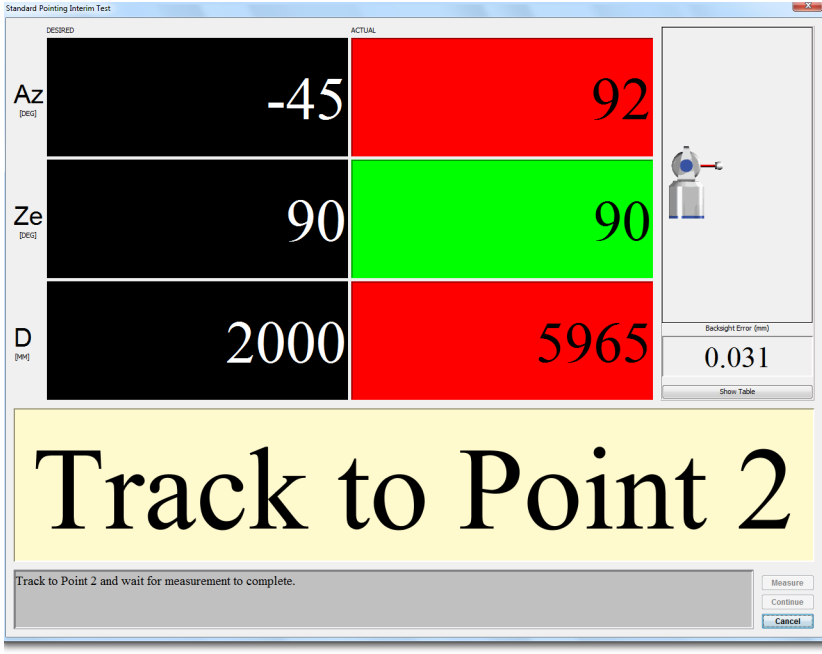


Figure 11-8 Guided and User Selected Points - Track to Point 2

5. After completing the last backsight measurement, click the **Continue** button. You will see the results of this check in the ANGULAR ACCURACY RESULTS dialog box.

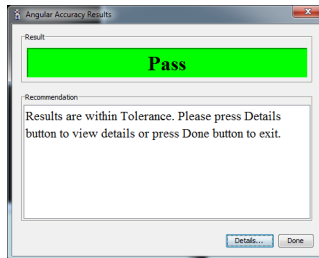


Figure 11-9 Angular Accuracy Results dialog box

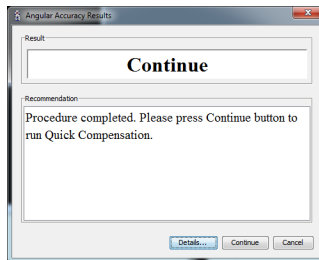
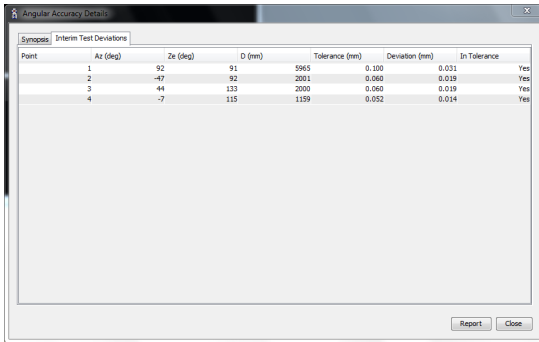


Figure 11-10 Angular Accuracy Check complete

CompIT compares the measured Angular Accuracy to the Vantage's Maximum Permissible Error (MPE) based on your Vantage's specifications per the ASME B89.4.19 Standard. The Results Dialog box will report PASS if the results are in tolerance and will report **Continue** with a recommendation to run the Quick Compensation Routine if they are out of tolerance.

6. Click **Done**, or **Continue** to follow CompIT's recommendation, or click **Details** to see the detailed results.

Click the **Angular Accuracy Check Deviations** tab to view the detailed results of the backsight measurements. The measurement location, the error, the tolerance (MPE) and if the measurement is In Tolerance or Out of Tolerance appears.



The screenshot shows a window titled "Angular Accuracy Details" with a tab labeled "Interim Test Deviations". The window contains a table with the following data:

| Point | Az (deg) | Zr (deg) | D (mm) | Tolerance (mm) | Deviation (mm) | In Tolerance |
|-------|----------|----------|--------|----------------|----------------|--------------|
| 1 | 92 | 91 | 5965 | 0.100 | 0.031 | Yes |
| 2 | -97 | 92 | 2001 | 0.060 | 0.019 | Yes |
| 3 | 44 | 133 | 2000 | 0.060 | 0.019 | Yes |
| 4 | -7 | 115 | 1159 | 0.052 | 0.014 | Yes |

At the bottom right of the window, there are two buttons: "Report" and "Close".

Figure 11-11 Angular Accuracy Check Deviations tab

7. Click **Close** to continue.
8. The Angular Accuracy Checks automatically close.

Quick Compensation

Quick Compensation is a routine that adjusts parameters in the Laser Tracker Measuring Head to improve its accuracy. Its purpose is to provide Angular Accuracy Results that are within your Vantage's specifications for the current working range of the system, or lower than the Vantage's Maximum Permissible Error (MPE) based on your Vantage's specifications per the ASME B89.4.19 Standard.

Quick Compensation can be performed prior to performing the Angular Accuracy Checks using the steps below. When running the Quick Compensation prior to performing the Angular Accuracy Checks, FARO recommends that you verify the Quick Compensation results with an Angular Accuracy Check.

NOTE: Quick Compensation is the preferred compensation for most applications, however Pointing Compensation from the Advanced tab of CompIT can yield lower backsight error or improved Angular Accuracy results, especially at longer distances, or when the full range of the system is required. Therefore, for measurement applications that require the highest possible accuracy and when measuring at long distances, Pointing Compensation can produce an improvement in overall measurement accuracy.

Equipment

The Quick Compensation requires a 1.5" Spherically Mounted Retroreflector (SMR) and a stable nest to place hold the SMR. You can use either the Calibration Tripod or heavy duty nests attached to your part. Several measurements are taken to ensure movement, vibration, etc does not affect the compensation, therefore if the nest or environment is not stable during the duration of the measurement, the Quick Compensation may not be able to finish.

Procedure

1. In the CompIT dialog box, click the Quick Compensation button. This step is not necessary if you chose to continue onto the Quick Compensation directly from the results of the Angular Accuracy Checks.
2. CompIT begins the Quick Compensation routine. This routine requires tracking the SMR to one location. The routine takes approximately five minutes to complete.

3. Place the SMR in the Home position and wait until the measurement of the SMR is complete.

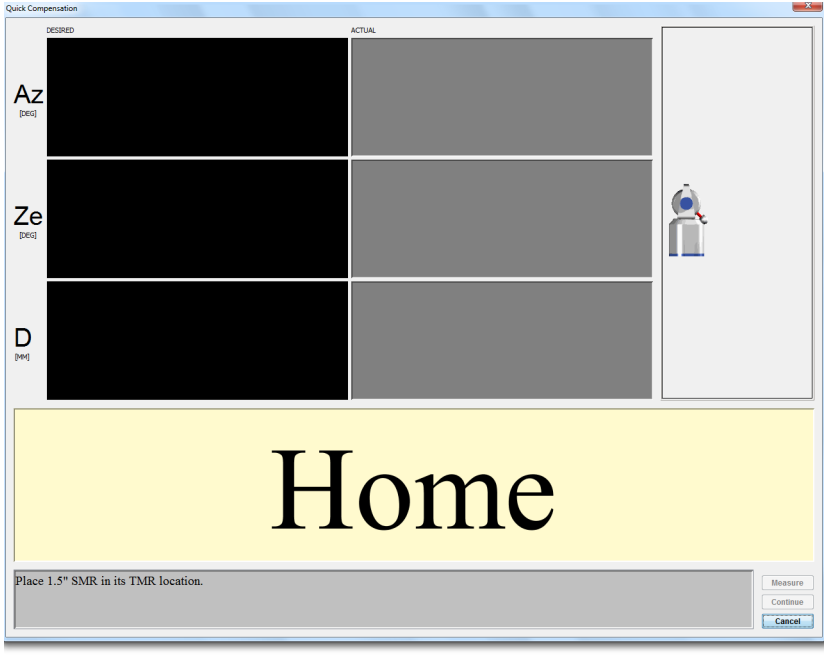


Figure 11-12 Quick Compensation - Home

4. Track the SMR to any location.

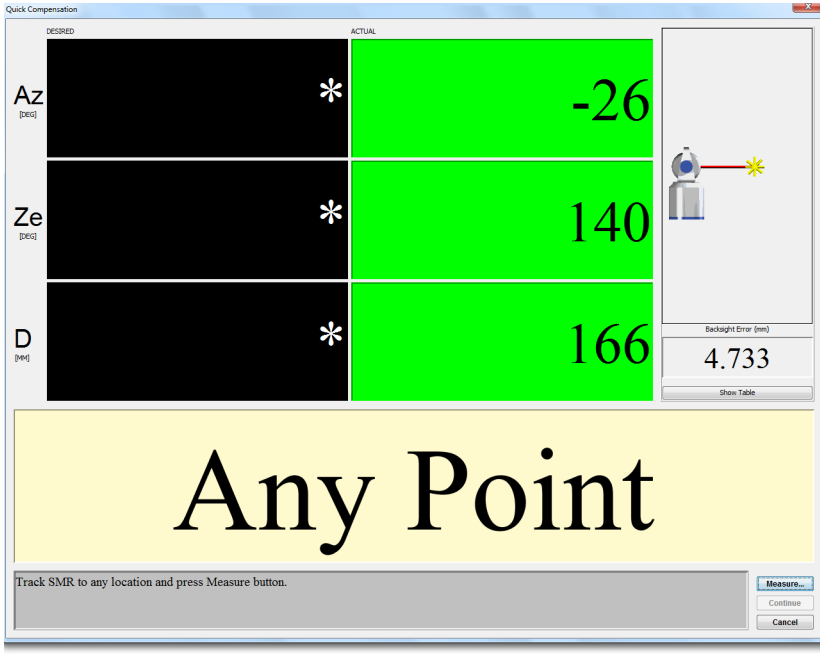


Figure 11-13 Quick Compensation - Track to Any Point

- CompIT automatically checks for stability of the SMR at the location.

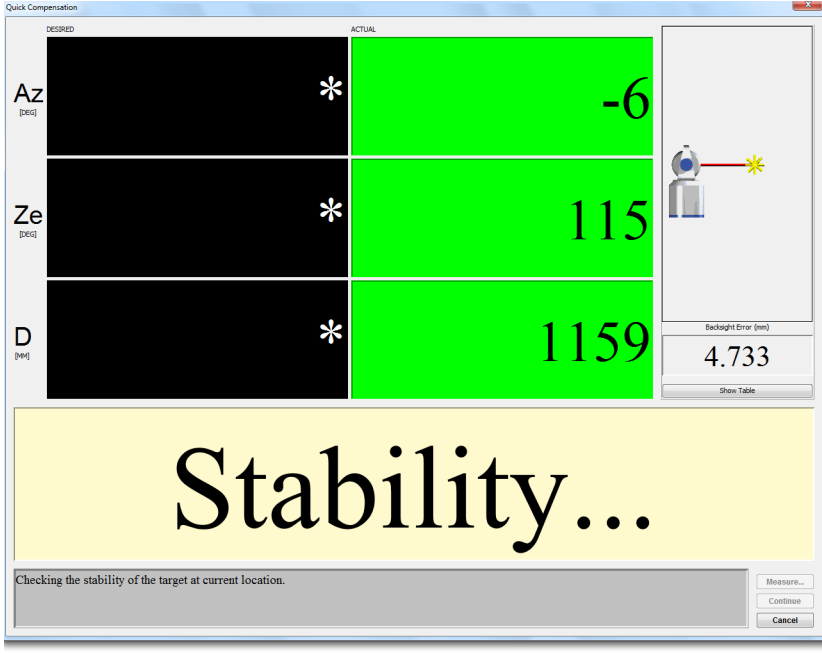


Figure 11-14 Quick Compensation - Checking Stability

- Once stable, CompIT automatically measures the location in both front sight and back sight modes.

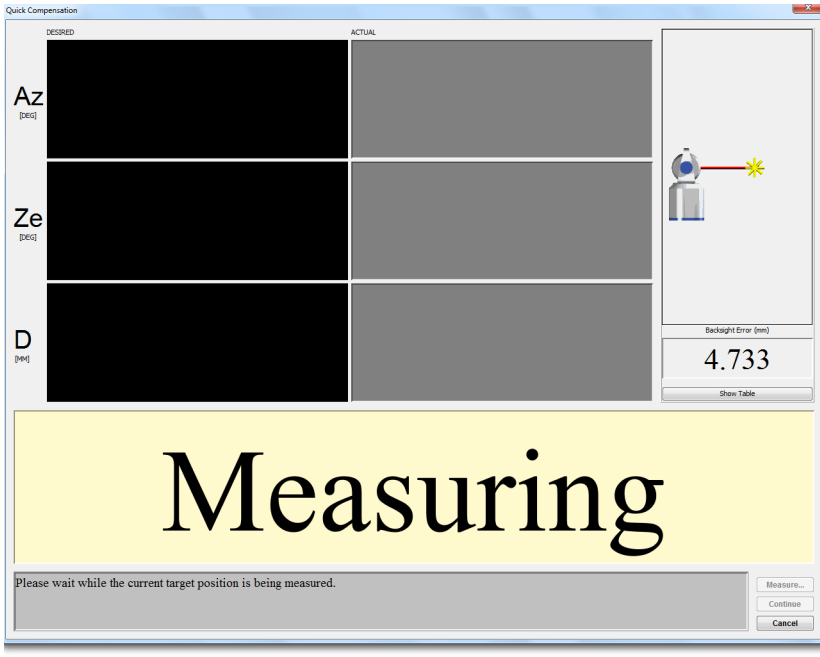


Figure 11-15 Quick Compensation - Measuring

5. After the routine is completed, you will see the results in the QUICK COMPENSATION RESULTS dialog box with a recommendation.
 - If Quick Compensation was run directly from the CompIT dialog box, click **Update** to update the Vantage compensation parameters.

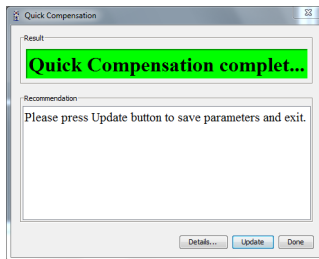


Figure 11-16 Quick Compensation - Passing Results

- If Quick Compensation was run directly from an Angular Accuracy Checks that did not have a passing results, the previous Angular

Accuracy Checks measurements will be used to verify that the Quick Compensation has improved the Vantage’s angular accuracy and it is now within its specifications. If these new results are not within the Vantage’s accuracy specifications, CompIT will recommend that you press CONTINUE to perform a Pointing Interim Test and Pointing Compensation. See “Pointing Compensation” on page 94.

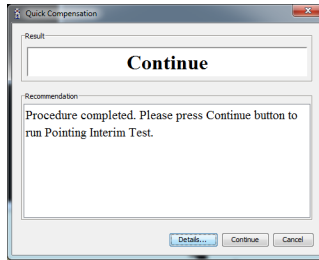


Figure 11-17 Quick Compensation - Passing Results

- Click **Done** to exit the Quick Compensation routine without making any updates.

CAUTION: The Laser Tracker Measuring Head’s compensation will not be changed. Click **Update** to use the previous measurements to improve the Vantage’s accuracy.

- Click **Details** to see detailed results.

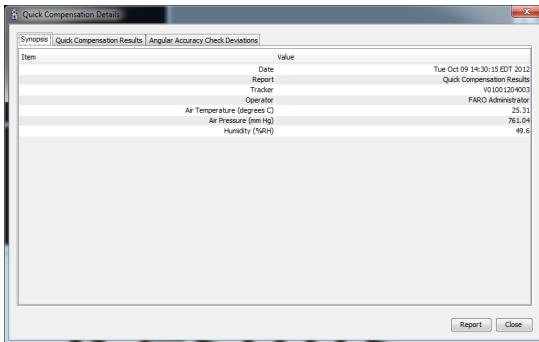


Figure 11-18 Synopsis tab

- Click Report to save the results to a text file.

If Quick Compensation was run directly from an Angular Accuracy Checks that did not have a passing results, an ANGULAR ACCURACY CHECK DEVIATIONS appears. Click this tab to view the new backsight results of the previously measured points. Also view the measurement location, the

error, the tolerance (MPE) and if the measurement is In Tolerance or Out of Tolerance. Click the **Quick Compensation** tab to view the Before, After and Change in system parameters. Quick Compensation adjusts the two rotational (RX and RY) and two translational (CTX and CTY) parameters. While these parameters are displayed and able to be saved for archival purposes, the values or the change do not indicate the current angular accuracy or backsight error of the Laser Tracker Measuring Head. The Angular Accuracy Checks or Backsight results is used to evaluate the accuracy of the Laser Tracker Measuring Head, not these parameters.

| Parameter | RX (rad) | RY (rad) |
|-----------|----------|-----------|
| Before | 0.001714 | 0.002091 |
| After | 0.001716 | 0.002088 |
| Change | 0.000002 | -0.000003 |

Figure 11-19 Quick Compensation Results tab

Advanced Tab

Clicking the Advanced tab on CompIT shows additional items that are used in less often than the items on the General tab:

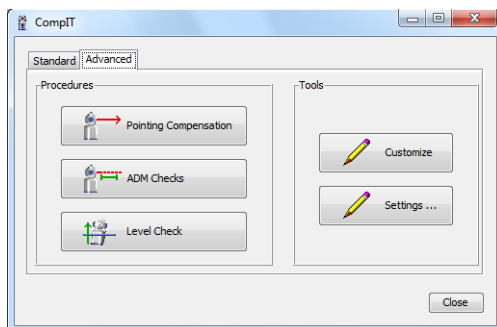


Figure 11-20 FARO CompIT dialog box - Advanced tab

The Advanced tab of the CompIT dialog box contains: Pointing Compensation, ADM Checks, Level Check, Customize and Settings.

See “Pointing Compensation” on page 94, “ADM Checks” on page 105, “Level Check” on page 115, “Customize” on page 117, and “Settings” on page 117.

Pointing Compensation

The Pointing Compensation, similar to the Quick Compensation, is a routine that adjusts parameters in the Laser Tracker Measuring Head to improve its accuracy. The purpose of both compensations routines is to provide Angular Accuracy Results that are within your Vantage’s specifications for the full range of the system, or lower than the Vantage’s Maximum Permissible Error (MPE) based on your Vantage’s Specifications per the ASME B89.4.19 Standard.

Compared to the Quick Compensation, the Pointing Compensation requires additional measurements and time to perform. Therefore the Quick Compensation is the preferred compensation for most applications. However, compared to the Quick Compensation, the Pointing Compensation can yield lower backsight error or improved Angular Accuracy results, especially at longer distances. Therefore, for some measurement applications, especially when measuring at long distances, Pointing Compensation can produce an improvement in overall measurement accuracy.

The Pointing Compensation consists of three parts:

- **Pointing Interim Test:** A preliminary check of the Angular Accuracy or backsight error at various locations in the Laser Tracker Measuring Head’s working volume.
- **Pointing Compensation:** Measurements taken at specific distances from the Laser Tracker Measuring Head. The purpose of these points is to improve the Angular Accuracy as the radial distance from the Laser Tracker Measuring Head increases.
- **Axis Non-Squareness Compensation:** Additional measurements that may further improve the Angular Accuracy. The purpose of these points is to improve the Angular Accuracy as the Laser Tracker Measuring Head’s Zenith axis changes.

Equipment

The Pointing Interim Test and Compensations will require a 1.5" Spherically Mounted Retroreflector (SMR) a stable nests to place the SMR in. Use either the Calibration Tripod or heavy duty nests attached to your part.

If the nests are not stable during the duration of the measurement, the Pointing Interim Test and Compensations may not be able to finish or the results can be poor.

Setup

Use this procedure with the Laser Tracker Measuring Head in the normal upright position and requires an area that can accommodate the following:

- Placing a target located at the same elevation as the Laser Tracker Measuring Head at a maximum distance of 10 meters.
- The origin of the Laser Tracker Measuring Head (center of the beam steering assembly) approximately 1.25 m to 1.65 m above the floor.

Procedure

NOTE: For best results, allow the Laser Tracker Measuring Head thermally stabilize in the working environment.

Pointing Interim Test

1. In the CompIT dialog box, click the **Advanced** tab and then click the **Pointing Compensation** button. This routine requires measurement at the Home position and the following locations:

- 90 degrees azimuth, 90 degrees zenith, 6 meters distance.
- -45 degrees azimuth, 90 degrees zenith, 2 meters distance.
- 45 degrees azimuth, 135 degrees zenith, 2 meters distance.
- Any user defined positions.

NOTE: You can loosen the mandrel mount and rotate the Laser Tracker Measuring Head to adjust the Azimuth angle to the target. Make sure to tighten the mandrel mount during the Stability check.

2. Place the SMR in the Home position and wait until the measurement of the SMR is complete.

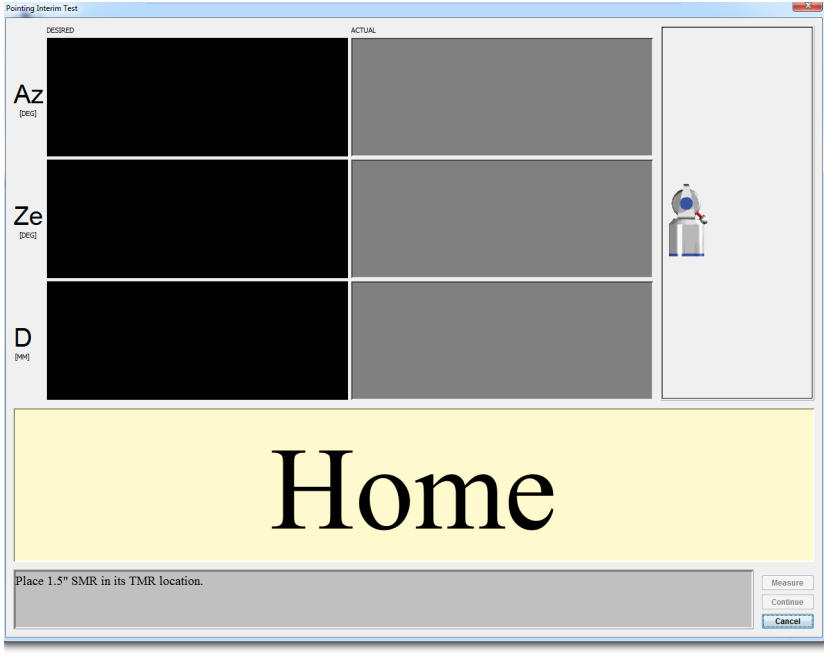


Figure 11-21 Pointing Compensation - Home

3. Track the SMR to the first location. CompIT checks for stability at the location and then automatically measures the location in both front sight and backsight modes. The calculated difference between the two measurements is the Backsight Error.

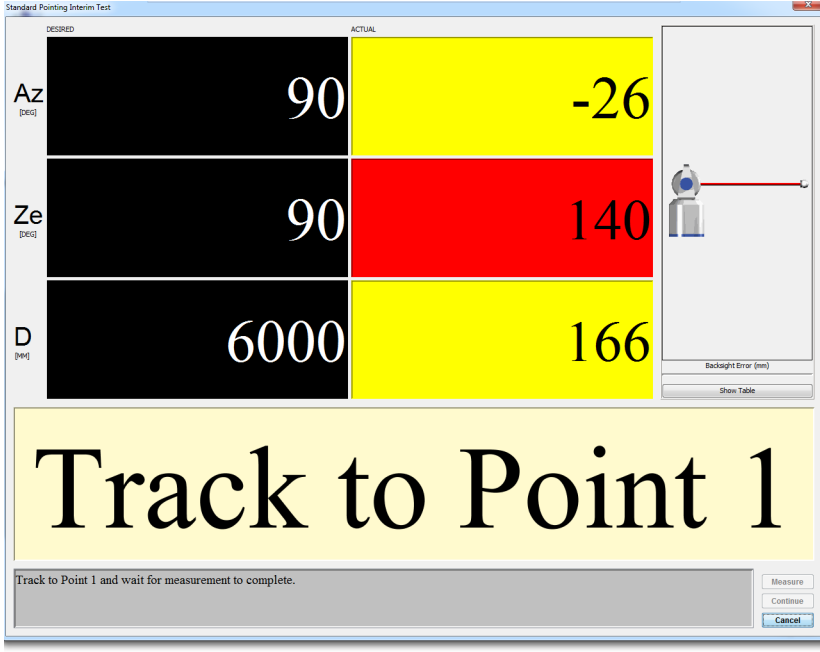


Figure 11-22 Pointing Compensation - Track to Point 1

- **DESIRED** value: The target values for Azimuth, Zenith, and Radial Distance.
- **ACTUAL** value: The current Azimuth, Zenith, and Radial Distance values of the SMR. The angle and distance values will be either red or yellow until you track the SMR to the desired values. The Radial distance value switches to red if the SMR is beyond its desired value. The values switch to green when the SMR is in an acceptable zone. When all of the values are green, the system waits five (5) seconds for stability before measuring the SMR.

NOTE: Check the tightness of the mandrel each time by trying to manually rotate the Laser Tracker Measuring Head on the instrument stand.

- **Backsight Error:** The backsight error or the previously measured point. Click the **Show Table** button to show a list of the backsight errors for all of the previously measured points.
 - **Cancel:** Exits the Interim Test without saving any data or parameters.
4. Track the SMR to the second location. CompIT checks for stability at the location and then automatically measures the location.

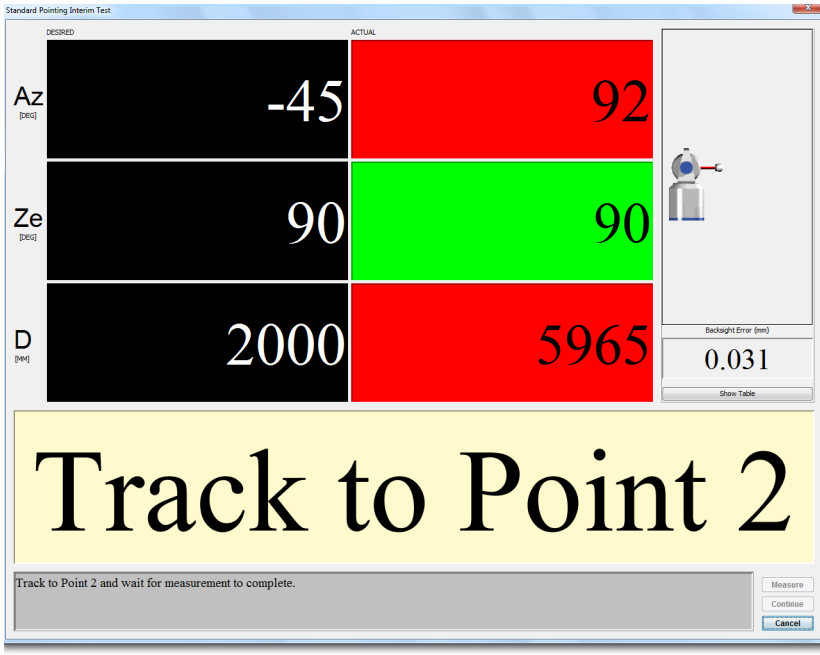


Figure 11-23 Pointing Compensation - Track to Point 2

- Track the SMR to the third location. CompIT checks for stability at the location and then automatically measures the location.

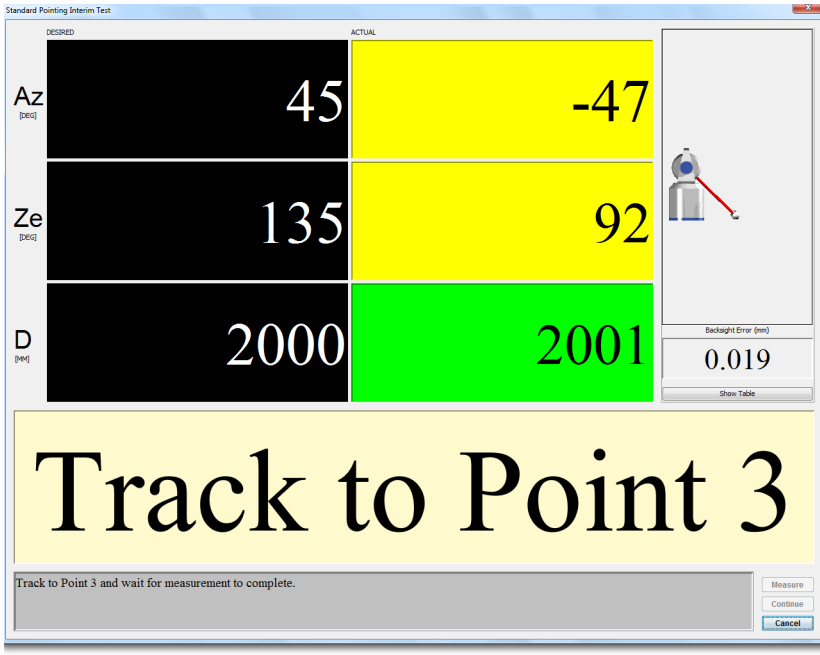


Figure 11-24 Pointing Compensation - Track to Point 3

- Track the SMR to a user defined location. CompIT checks for stability at the location and then automatically measures the location.

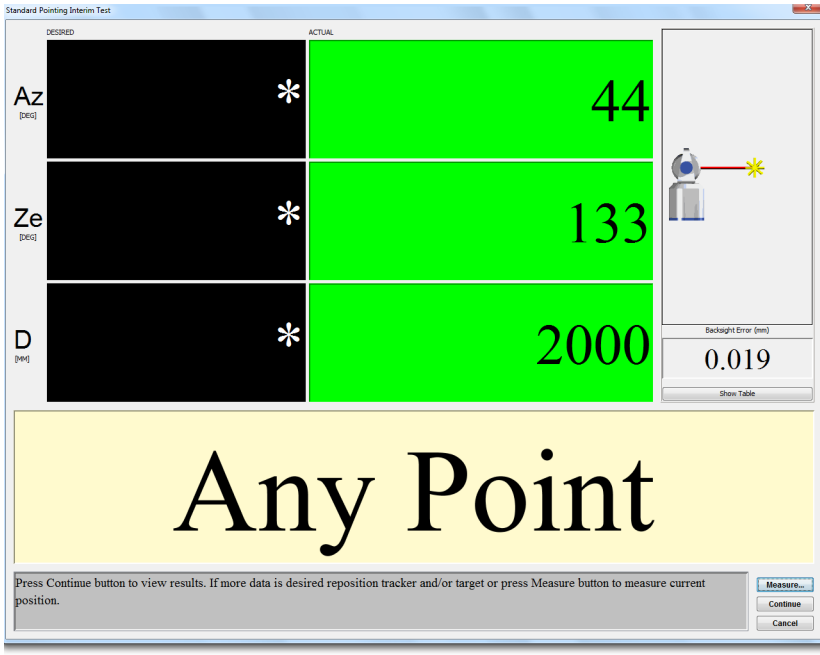


Figure 11-25 Pointing Compensation - Track to Any Point

You can continue measuring “user-defined locations.” These locations should include the full working volume or create an envelope around the object you are currently measuring. Examples include control points and points near the extreme of your part.

- After completing the last measurement, click **Continue**. You will see the results of this test in the ANGULAR ACCURACY RESULTS dialog box.

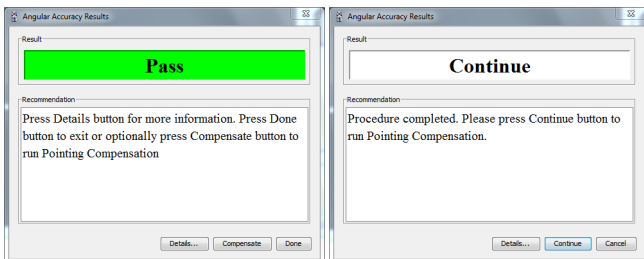


Figure 11-26 Pointing Interim Test results

8. CompIT will make a recommendation based on the results of the Interim Test:
 - If all of the points are in tolerance or below the Maximum Permissible Error, accurate measurements will be able taken with the Laser Tracker Measuring Head and CompIT will report a result of PASS. Click **Done** to exit and return to the CompIT dialog box. You can optionally click **Compensate** to continue on with the Pointing Compensation to further improve the Angular Accuracy.
 - If one or more points are out of tolerance or greater than the Maximum Permissible Error, CompIT recommends continuing onto the Quick Compensation. Click **Continue** to start the Quick Compensation routine.
 - Click the **Details** button to view detailed results. Click the **Report** button to save the results to a text file.

Pointing Compensation

Clicking **Compensate** in the ANGULAR ACCURACY RESULTS dialog box appears the STANDARD POINTING COMPENSATION dialog box. This routine requires measurement at the Home position and the following locations:

- any azimuth position, 90 degrees zenith, 2.0 meters distance.
 - any azimuth position, 90 degrees zenith, 3.6 meters distance.
 - any azimuth position, 90 degrees zenith, 5.2 meters distance.
 - any azimuth position, 90 degrees zenith, 6.8 meters distance.
 - any azimuth position, 90 degrees zenith, 8.4 meters distance.
 - any azimuth position, 90 degrees zenith, 10.0 meters distance.
1. Place the SMR in the Home position and wait until the measurement of the SMR is complete.
 2. Place the SMR in the calibration tripod or in another stable nest and track the SMR to the first desired location. CompIT checks for stability and automatically measures the point in both front sight and back sight modes.
 3. Continue for each of the remaining desired locations.

4. After completing the last measurement, click **Continue**. You will see the results of this test in the ANGULAR ACCURACY RESULTS dialog box.

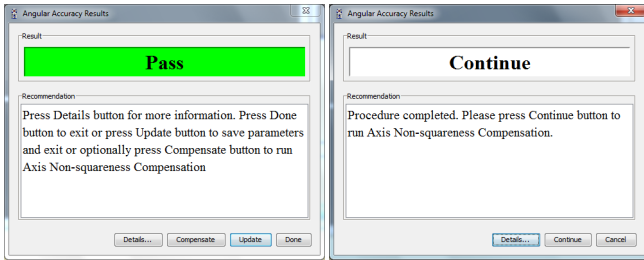
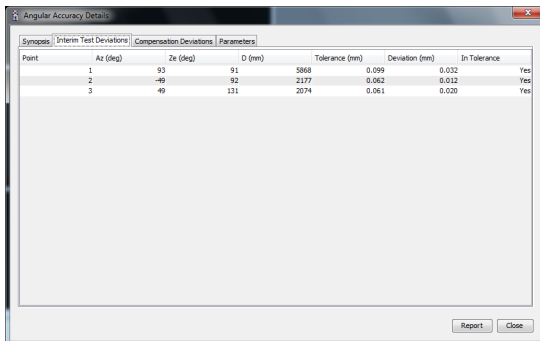


Figure 11-27 Pointing Compensation Results

CompIT will calculate new parameters generated by the Pointing Compensation, apply them to the previously measured Interim Test Points and make a recommendation based on these results:

- If all of the points are in tolerance or below the Maximum Permissible Error, accurate measurements will be able taken with the Laser Tracker Measuring Head and CompIT will report a result of PASS. Click **Update** to save the results and exit the routine. You can optionally press **Compensate** to continue on with the Axis Non-Squareness Compensation to further improve the Angular Accuracy.
- If one or more points are out of tolerance or greater than the Maximum Permissible Error, CompIT recommends continuing onto the Axis Non-Squareness Compensation. Press **Continue** to start the Axis Non-Squareness Compensation routine.
- Click DETAILS to view detailed results. The REPORT button on the Details page can be used to save the results to a text file.



| Point | Az (deg) | Zc (deg) | D (mm) | Tolerance (mm) | Deviation (mm) | In Tolerance |
|-------|----------|----------|--------|----------------|----------------|--------------|
| 1 | 93 | 91 | 5869 | 0.099 | 0.032 | Yes |
| 2 | -49 | 92 | 2177 | 0.062 | 0.012 | Yes |
| 3 | 49 | 131 | 2074 | 0.061 | 0.020 | Yes |

Figure 11-28 Pointing Compensation Results - Interim Test Deviations

Click the **Parameters** tab to view the Before, After and Change in system parameters. Pointing Compensation adjusts the two rotational (RX and RY) and two translational (CTX and CTY) parameters.

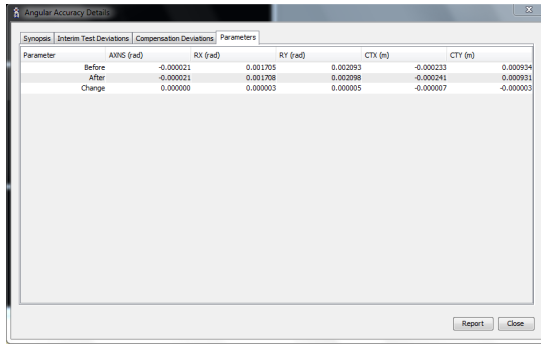


Figure 11-29 Pointing Compensation Results - Parameters

NOTE: The information presented on the PARAMETERS tab is for information only. The Angular Accuracy Checks or Backsight results is used to evaluate the accuracy of the Laser Tracker Measuring Head, not these parameters.

- Click REPORT to save the results to a text file.
- Click CLOSE to exit and return to the ANGULAR ACCURACY RESULTS dialog box.

Axis Non-Squareness Compensation

This routine requires measurement at the Home position and the following locations:

- 0 degrees azimuth, 135 degrees zenith, 2.0 meters distance.
- 0 degrees azimuth position, 110 degrees zenith, 4.0 meters distance.
- 0 degrees azimuth position, 110 degrees zenith, 4.0 meters distance.
- 0 degrees azimuth position, 102 degrees zenith, 6.0 meters distance.

1. Place the SMR in the Home position and wait until the measurement of the SMR is complete.
2. Place the SMR in the calibration tripod or in another stable nest and track the SMR to the first desired location. CompIT checks for stability and automatically measures the point in both front sight and back sight modes.
3. Continue for each of the remaining desired locations.

4. After completing the last measurement, click **Continue**. You will see the results of this test in the ANGULAR ACCURACY RESULTS dialog box.

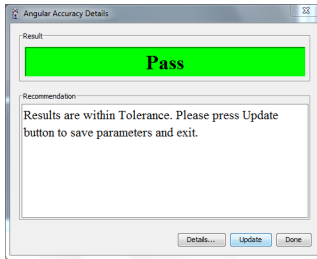


Figure 11-30 Axis Non-squareness Compensation results

- Click UPDATE to save the results to the Laser Tracker System.
- Click DONE to exit the Axis Non-squareness routine without saving the results.
- Click DETAILS to see the results.

ADM Checks

The ADM Interim Test compares the distance between two points measured from a position that uses a large amount angular rotation to the distance between the same two points measured from a position that uses almost all radial measurements or a very small amount of angular rotation. These two measurement orientations have different sources of error and can therefore be used as a field check for the Vantage's ADM System.

FARO recommends to perform this test immediately after performing a Pointing Compensation.

Equipment

The ADM Interim Test will require a 1.5" Spherically Mounted Retroreflector (SMR) and two stable nests to place the SMR in. The Calibration Tripod used for the Angular Accuracy Checks and Pointing Compensations cannot be used for this test. Two points glued to the floor can be used but two points on heavy duty instrument stands can provide better alignment percentages.

Alternatively, you can perform this test with a bar with two fixed targets where the bar moves to different locations and the Laser Tracker Measuring Head remains in the same location. If you use a bar with two fixed targets, securely mount the bar during the measurements to prevent any changes in its length from bending or flexing.

Procedure

For best results, FARO recommends to run this test immediately after performing a Pointing Compensation from the **Advanced** Tab. See "*Pointing Compensation*" on page 94.

1. In the CompIT dialog box, click the **Advanced** tab and then click the **ADM Checks** button.

The first position for the interim test is with the Laser Tracker Measuring Head set up to measure two points from the side. This setup should maximize the use of the Laser Tracker Measuring Head's angular encoders. FARO recommends to set up the Laser Tracker Measuring Head three (3) meters away from two points that are one (1) or more meters apart. After measuring the second point, the software reports the percentage of the measurement that is made with the encoders. FARO recommends a percentage of 80% or higher to obtain a meaningful result in this test. To obtain a percentage of 80% from this position, place the points at the following locations:

- Point 1: 110 degrees Azimuth, 90 degrees Zenith, 3000 mm Radial Distance
- Point 2: 80 degrees Azimuth, 90 degrees Zenith, 3000 mm Radial Distance

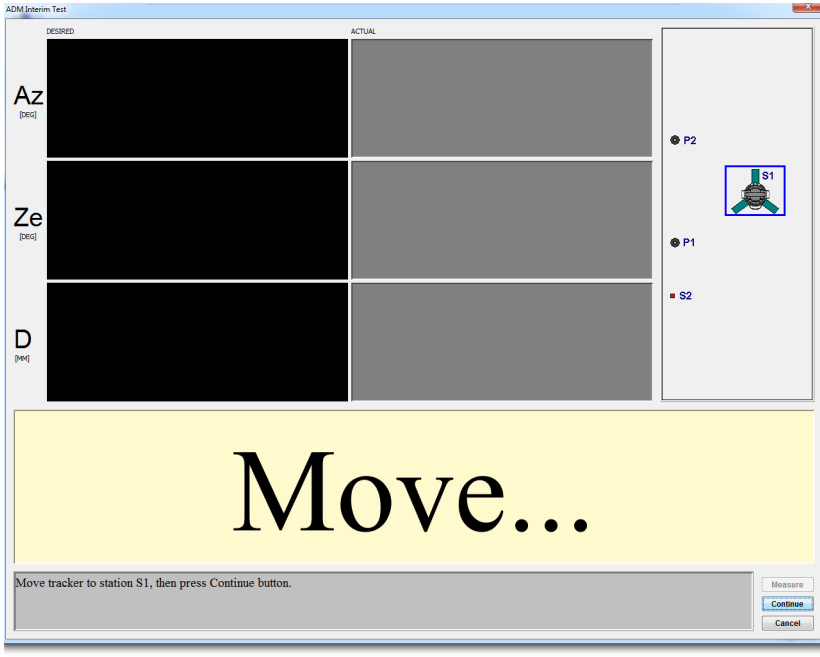


Figure 11-31 Move to Station S1

2. Move the Laser Tracker Measuring Head to Station S1 and click Continue.
3. Move the SMR to the Home position. An auto-adjust completes at the Home position to normalize the ADM for the test.

4. Track or send the beam to Point 1. To send the beam, click **Motors Off** and manually steer the beam to the target.

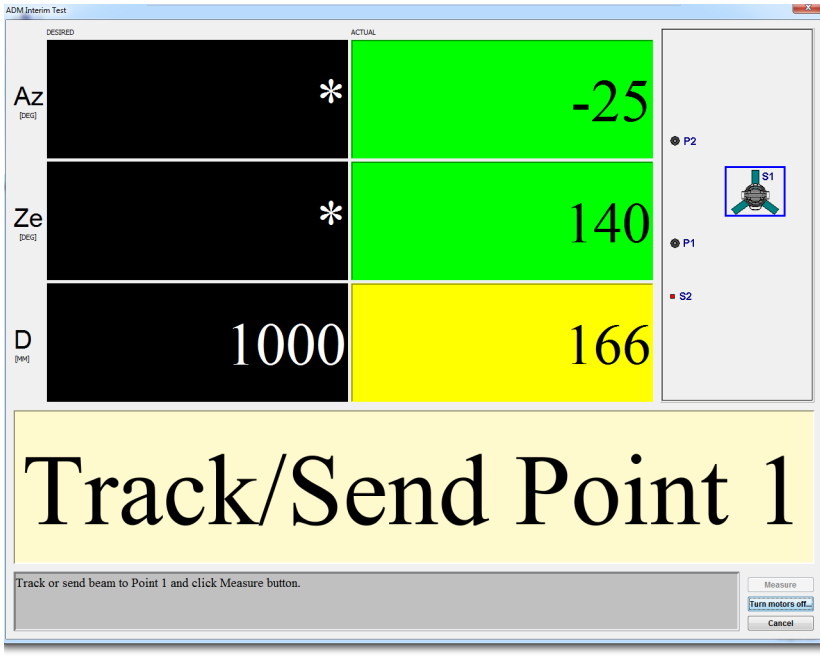


Figure 11-32 Beam to Point 1

5. Measure Point 1 by clicking **Measure**. A check is made to ensure the target is stable and then the measurement is taken.

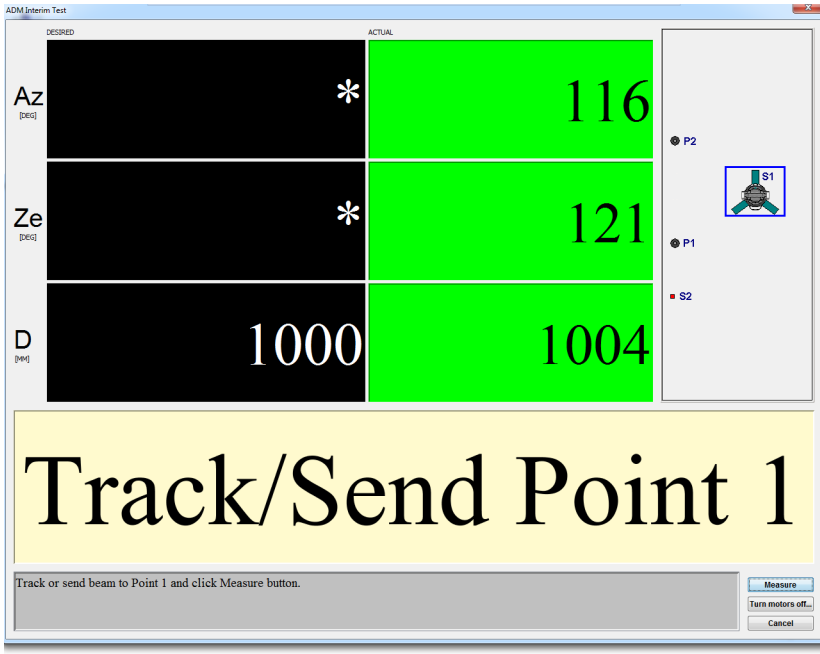


Figure 11-33 Measure Point 1

- Track, or send, the beam to Point 2. A pie chart indicates the percentage of the measurement that is made with the angular encoders. FARO recommends to achieve a percentage of greater than 80%. If the target position yields a number lower than 80%, a message box appears and tells you where to move the SMR.

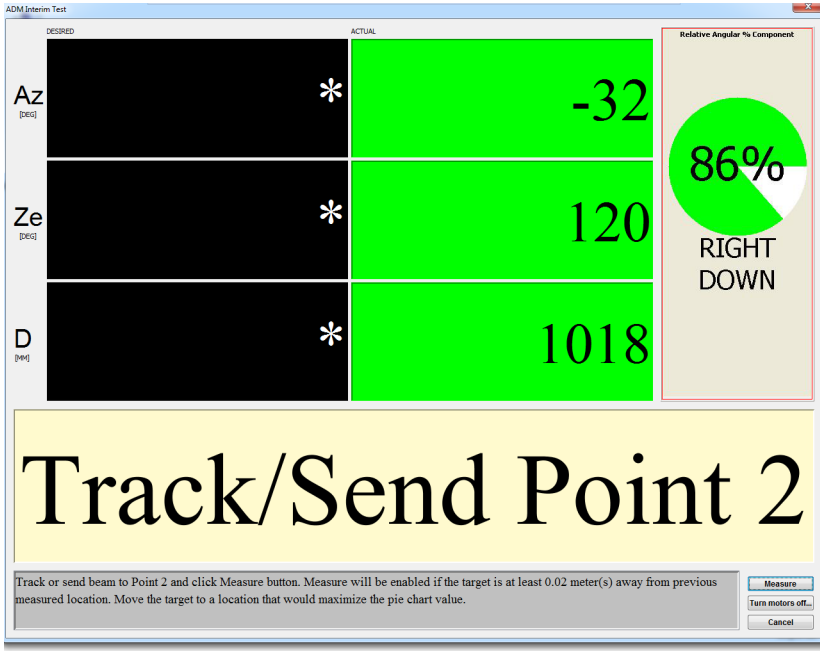


Figure 11-34 Beam to Point 2

- Click **Measure** to measure Point 2.

8. If the pie chart shows a percentage greater than 80%, the setup for the first measurement is good. Click **Continue** to proceed. If the percentage is less than 80% FARO recommends that you re-measure. Click **Retry** to re-measure the two points with a setup that yields greater than 80%.

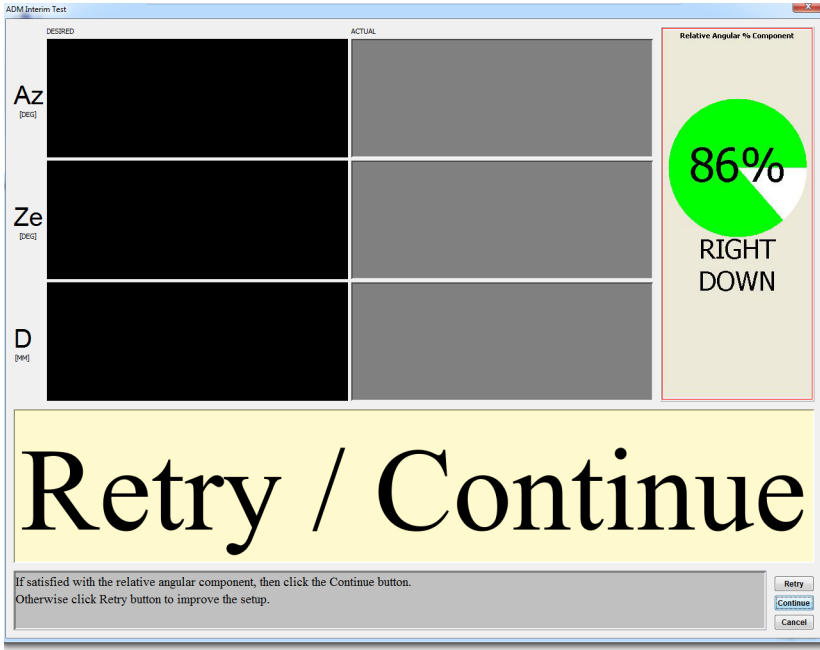


Figure 11-35 Retry/Continue 2

Position #2

1. Move the Laser Tracker Measuring Head to Position 2. Position 2 should orient the Laser Tracker Measuring Head in such a way as to maximize the distance measurement component of the measurement; that is, the laser beam should be in line with the two measurement points. Use a range of 1 to 2 meters from point one; however, you can use any distance.

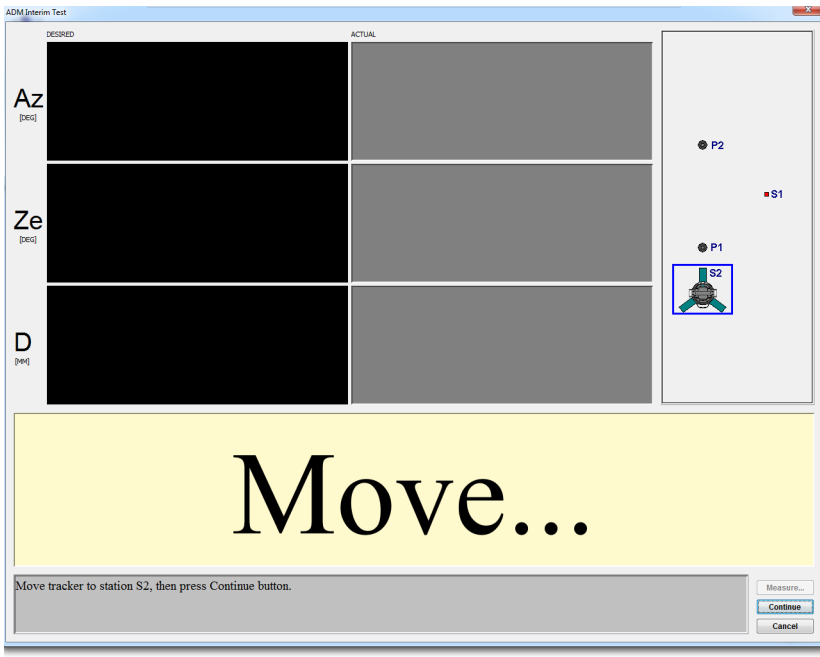


Figure 11-36 Move to Position 2

2. Click **Measure** to measure Point 1. A check is made to ensure the target is stable before the measurement is taken.

- Track or send the beam to Point 2. A pie chart indicates the percentage of the measurement that is made with ADM. FARO recommends to use a percentage of greater than 80%. If the target position yields a number lower than 80%, a message box appears and tells you where to move the Laser Tracker Measuring Head (or bar if a bar with two targets is used).

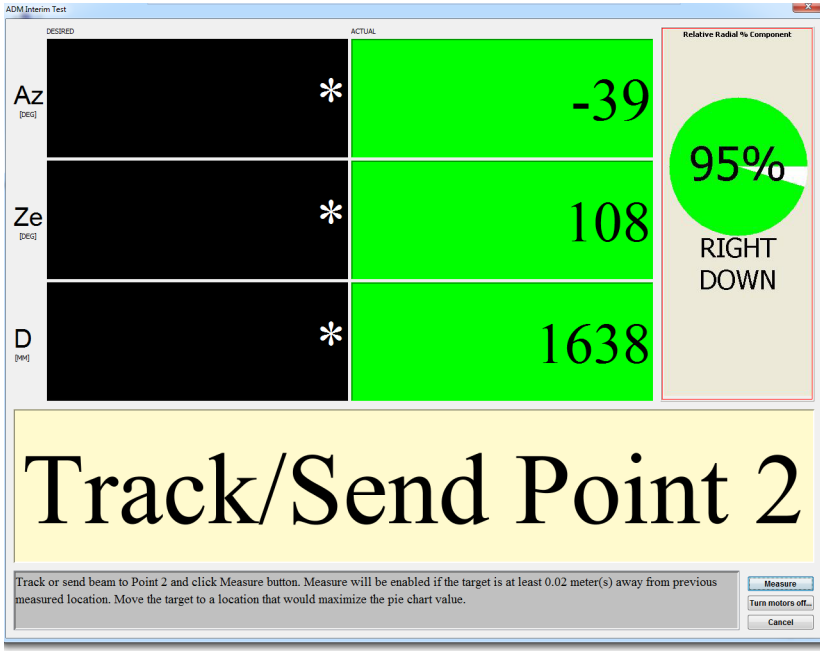


Figure 11-37 Beam to Point 2

- Click **Measure** to measure Point 2.
- If the pie chart shows a percentage greater than 80%, then the setup for the second position is good. Click **Continue** to proceed. If the percentage is less than 80% FARO recommends that you move the Laser Tracker Measuring Head and re-measure. Click **Retry** to re-measure the two points with a setup that yields greater than 80%.

- The ADM IT results dialog indicates the distances measured between the two points from the two setups and the percentage of angular and distance measurements. A result from setups with greater than 80% indicates a valid test. The difference between the two measurements is shown along with the Maximum Permissible Error (MPE), which is derived from the system's angular specifications. A result (Pass/Fail) appears.

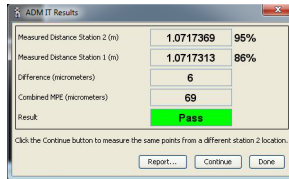


Figure 11-38 ADM IT Checks dialog box

- Clicking on the **Report** button opens a dialog to save the results to a comma delimited text file. A check box is available to append the report to a previous report. Appending the report creates a log file of the test results. Click **Done** to close the results page.

- The **Measure More Points** button returns to the Move screen and prompts for another set of two points from another Laser Tracker Measuring Head (or bar) position. This allows for additional distances to be measured in the testing of the ADM. For example, measure from two (2), four (4), and six (6) meters.

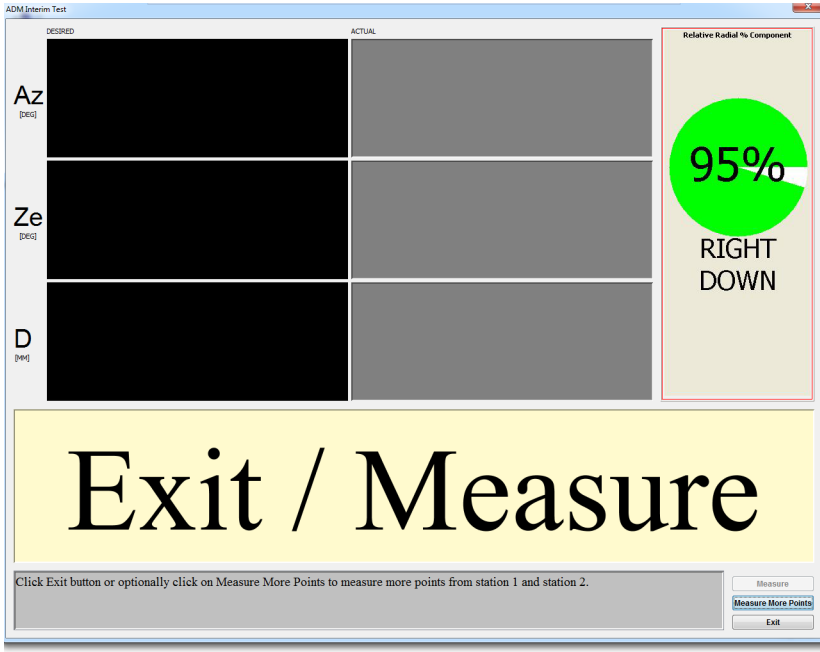


Figure 11-39 Measure More Points

- Click **Exit** to end the test.

Level Check

The Level Check verifies that the Laser Tracker Measuring Head's level sensor is able to measure accurately. It compares its angular measurements to the Laser Tracker Measuring Head's angular encoders while moving the axis in very small increments.

Equipment

The Level Check requires the Laser Tracker Measuring Head to be setup on a stable stand in the upright position and leveled out using the Laser Tracker Measuring Head's Electronic Bubble Level from the TrackerPad. See "TrackerPad" on page 124. The Level Check does not require the use of any SMR's.

Procedure

1. In the CompIT dialog box, click the **Advanced** tab and then click the **Level Check** button. The Level Check will take approximately 5 minutes to complete. You will see the Laser Tracker Measuring Head's axis rotate around several times while performing the test.
2. Upon completion of the Level Check, the LEVEL CHECK RESULTS dialog box appears:

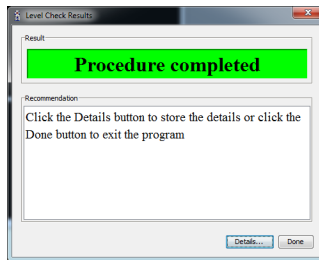


Figure 11-40 Level Check Results dialog box

Press **Details** to see the detailed results:

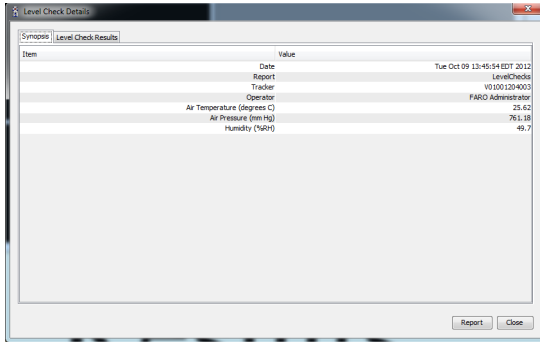


Figure 11-41 Level Check Details dialog box

- **Encoder Movement** (arc seconds): The angular movement of the Laser Tracker Measuring Head's axes measured by the its encoders.
 - **Level Movement** (arc seconds): The angular movement of the Laser Tracker Measuring Head's axes measured by the Level sensor.
 - **Difference** (arc seconds): The measured Level sensor error or difference between the two systems.
 - **MPE** (arc seconds): Maximum Permissible Error per the system's specifications.
 - **In Tolerance**: Yes if the measured error is below the MPE.
3. Click **Close** to exit the Level Check Results.
 4. The Level Checks procedure automatically exits.

Settings

By default, the Angular Accuracy Checks, the Pointing Interim Test and the ADM Checks automatically measures after the target is in a stable location. The CompIT settings allows you to change this.

In the CompIT dialog box, click the Advanced tab and then click the Settings button.

This opens the CompIT SETTINGS dialog box which has three check boxes to set the Auto Measure function for ADM, Angular Accuracy and Pointing Interim Tests.

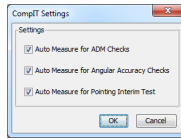


Figure 11-42 CompIT Settings dialog box

If any Auto Measure setting is clear, a Measure button is available in each dialog box. Click this button to manually start measuring in any of the tests.

- Click **OK** to apply any changes and continue.
- Click **Cancel** to exit without applying changes.

Customize

Use the Customize command to change the default settings of CompIT.

CAUTION: Changing parameters may result in a less than optimal compensation and decreased measurement accuracy.

In the CompIT dialog box, click the Advanced tab and then click the Customize button. This opens the CUSTOMIZE FARO CompIT dialog box which has four separate tabs which allow you to customize the General, Pointing Compensation, Repeatability, and Pointing Interim Test settings.

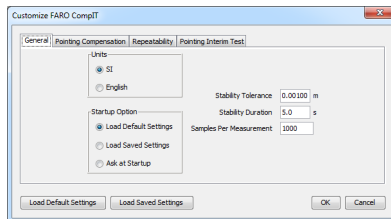


Figure 11-43 Customize dialog box

- Click **Load Default settings** to load the default or factory settings.

- Click **Load Saved settings** to load any settings that you have previously saved.
- Click **OK** to apply any changes and continue.
- Click **Cancel** to exit without applying changes.

General

Use the **General** tab in the CUSTOMIZE FARO COMPIT dialog box to set the general parameters of CompIT.

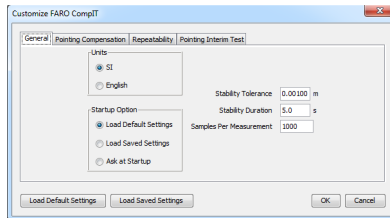


Figure 11-44 General tab

- **Units** - The unit of measurement for all of the routines when CompIT is started from the FARO Tracker Utilities program. Choose SI for Millimeters or English for Inches.
- **Stability Tolerance** - The maximum allowable movement of the SMR during the stability checks performed prior to an automatic measurement.
- **Stability Duration** - The amount of time the SMR must remain stable before the any measurement starts.
- **Samples Per Measurement** - The number of measurement samples for each measurement. Each measurement is an average of the samples.
- **Load Default Settings** - Choose this to load the factory default CompIT settings when starting CompIT.
- **Load Saved Settings** - Choose this to load custom CompIT settings saved to the computer when starting CompIT.
- **Ask at Startup** - Ask which setting you would like to use when starting CompIT, factory default or custom settings saved to the computer.

Pointing Compensation

Use the **Pointing Compensation** tab in the CUSTOMIZE FARO COMPIT dialog box to set the parameters for the Pointing Compensation routine.

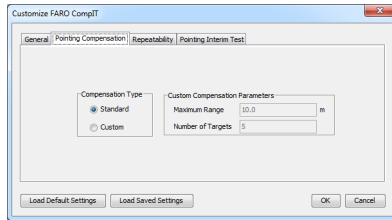


Figure 11-45 Pointing Compensation tab

Use the STANDARD Compensation Type or choose the CUSTOM radio button and set the following parameters:

- **Maximum Range:** The maximum distance for the ADM CompIT routine. Each desired distance locations is a proportional distance of the maximum distance.
- **Number of Targets:** The number of targets to measure in the routine.

Repeatability

Use the **Repeatability** tab in the CUSTOMIZE FARO COMPIT dialog box to set the repeatability parameters for CompIT.

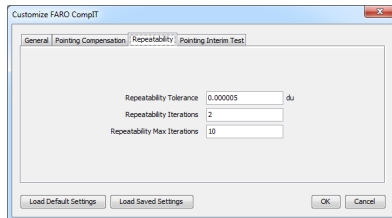


Figure 11-46 Repeatability tab

- **Repeatability Tolerance:** Set the maximum error for consecutive measurements for each location during the Pointing Compensation and Squareness Compensation.
- **Repeatability Iterations:** Set the number of repeating consecutive measurements for each location during the Pointing Compensation and Squareness Compensation.

- **Repeatability Max Iterations:** Set the maximum number of measurement attempts for each measurement before generating an error message prompts you to review your environment.

Pointing Interim Test

Use the **Pointing Interim Test** tab in the CUSTOMIZE FARO COMPIT dialog box to set the parameters for all Pointing Interim Tests.

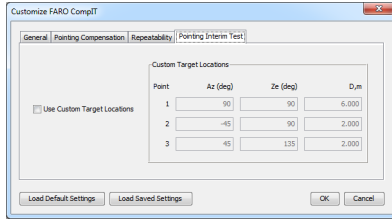


Figure 11-47 Pointing Interim Test tab

- Select the USE CUSTOM TARGET LOCATIONS check box and enter values for the three target locations.

Chapter 12: Configuring the FARO Laser Tracker Vantage in CAM2 Measure

The **DEVICES** tab of the CAM2 Measure ribbon contains all the commands for configuring and controlling your Vantage. You can also press the **P** hot key on the keyboard.

You can also use the Vantage in a measurement Survey. Surveying is an automated, repetitive measurement process used to track the position(s) of one or more targets over time. For more information about the **Survey** command, see the *Survey* section of the *Navigation Window* chapter in the CAM2 Measure manual.

NOTE: The Vantage is only compatible with CAM2 Measure v10.1 and later.



Hardware Configuration

The **Hardware Configuration** command accesses the **DEVICE CONTROL** panel and contains a list of all active (detected) devices. The **DEVICE CONTROL** panel contains a list of all active devices with the properties of each associated device. You can also press the **P** hot key to show the **DEVICE CONTROL** panel.

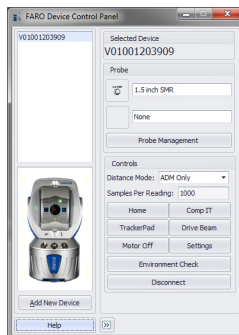


Figure 12-1 Device Control Panel

Choose a FARO Laser Tracker Vantage from the list to see the probe details.

- Click the >> button to hide the list of devices.
- Click the << button to show the list of devices.

Add a Device

From the DEVICE CONTROL panel, click the **Add New Device** button. Select an eligible device from the ADD NEW DEVICE dialog, enter your Vantage's IP address and click **Connect**.

NOTE: When set in Wired mode, the default IP address for a Vantage is 128.128.128.100. Find the Wireless mode IP address with the **Find Trackers** button tool in FARO Tracker Utilities. See *“Wireless Connection” on page 37*.

Multiple Laser Tracker Users

A lock system prohibits two or more users on different computers from performing write functions (such as changing probes, changing distance modes, etc.) to the same Vantage concurrently. Read functions (such as taking readings) are not affected by the lock system.

The DEVICE CONTROL panel will overwrite the probe setting in the device with the probe setting from the local file on startup, which creates a conflict if two users attempt to access the device with two different probe sizes.

For more information on connecting, configuring, and measuring with multiple Laser Trackers, see the *Multiple Devices* section of the *Devices* chapter in the CAM2 Measure manual.

Probes

The Probes section of the DEVICE CONTROL panel shows the current SMR and Adapter for the current Vantage.

Change Probe

From the DEVICE CONTROL panel, click the **Probe Management** button to show the FARO LASER TRACKER PROBE MANAGER dialog box.

- Choose an SMR.
- Choose an Adapter, if necessary.
- Click the OK button.

NOTE: You can also choose the SMR and Adapter from the drop-down lists in the MEASUREMENT panel. See *“Adding Readings” on page 133*.

Adding Adapters

The default list in the Adapters column of the FARO LASER TRACKER PROBE MANAGER dialog box are standard FARO adapters. Add, Edit or Delete a custom SMR adapter in the FARO LASER TRACKER PROBE MANAGER dialog box.

- Click the **Add** button to create a new adapter. In the CUSTOM ADAPTER dialog box:
 - Enter a name for the adapter.
 - If necessary, select the Custom Diameter check box and enter a value in the field.
 - Enter a height value in the Custom Height field.

Controls

The CONTROLS section of the DEVICE CONTROL panel contains all of the buttons to configure and control the Vantage. Some of these commands are available directly on the **Devices** tab of the CAM2 Measure ribbon.

Distance Mode: The Vantage operates using TruADM and the DISTANCE MODE drop-down list only contains the ADM Only option.

Samples Per Reading: Control the amount samples, or individual measurement of your target, for each reading of a CAM2 Measure measurement feature. These samples are best fit into a single reading.

Home

Click the **Home** button to send the Laser Tracker Measuring Head laser beam to the Tracker Mounted Reset (TMR) or Home position.

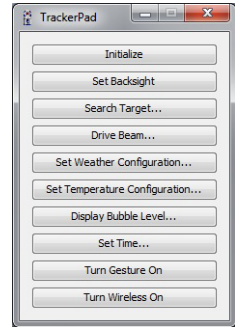
CompIT

Click the CompIT button to start FARO CompIT. *For more information, see “FARO CompIT” on page 77.*

TrackerPad

Click the **TrackerPad** button to start FARO TrackerPad. In the TRACKERPAD dialog box, you can:

- **Initialize** - Initialize the FARO Laser Tracker Vantage System.
- **Set Backsight** - Switch the Laser Tracker Measuring Head into backsight or frontsight measurement.
- **Search Target** - Initiate a search for a target.
- **Drive Beam** - Drive the Beam to a specific Location.
- **Set Weather Configuration** - View and configure the weather measurement settings.
- **Set Temperature Configuration** - View the temperature sensor configuration and change each sensors alarm settings.
- **Display Bubble Level** - View the bubble level.
- **Set Time** - Set the Time.
- **Turn Gesture On/Off** - Switch the Gesture On/Off.
- **Turn Wireless On/Off** - Switch the Wireless connection On/Off.



Initialize

Runs the angular encoder initialization sequence. This is necessary if the motors shut down. The Laser Tracker Measuring Head motors will shut down as a protective measure if the axis is forced or over-torqued.

Set Backsight

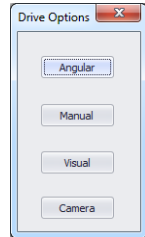
Switches the Laser Tracker Measuring Head between frontsight and backsight modes.

Search Target

Initiates a spiral search for a target.

Drive Beam

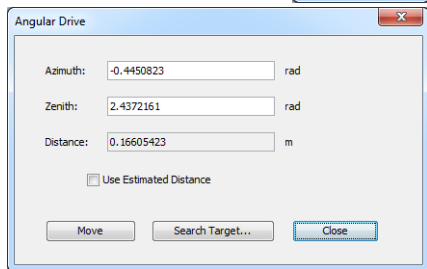
Drive Options: These options allow you to manually move, or drive, the laser beam to locations where tracking the SMR is difficult.



Angular Drive: Move the laser beam to a target by keying in specific azimuth and zenith positions.

To use the Angular Drive option:

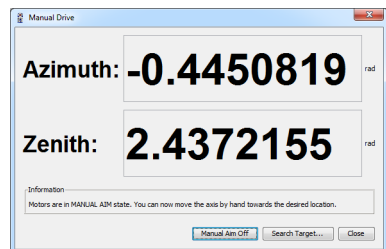
1. Enter the Azimuth and Zenith positions in radian units. If necessary, select the USE ESTIMATED DISTANCE check box and enter the estimated distance.
2. Click the **Move** button to move the laser beam to the position. Repeat until the laser beam is pointing near the target.
3. Click the **Search...** button, key in the search parameters, and click the **Search** button to acquire the target.
4. Click **Close** to exit the command.



Manual Drive: Manually move the laser beam to a target. Starting this command automatically switches the Laser Tracker Measuring Head's motors off.

To use the Manual Drive option:

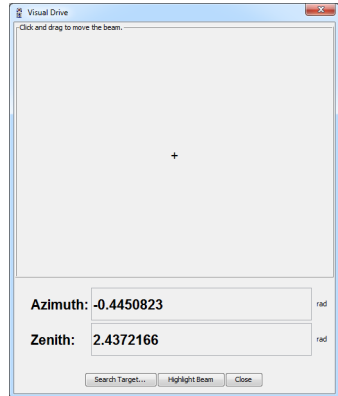
1. Carefully move the Laser Tracker Measuring Head and move the laser beam near the target.
2. Click the **Manually Aim Off** button.
3. Click the **Search** button to acquire the target.
4. Click the **Close** button to exit the command.



Visual Drive: Move the laser beam to a target using your computers mouse or arrow keys.

To use the Visual Drive option:

1. Click and hold near the cross hairs in the center of the dialog box.
2. Slowly drag the mouse in any direction until the Laser Tracker Measuring Head is pointing near the target. Use the arrow keys to direct the beam.
3. Click the **Search...** button, key in the search parameters, and click the **Search** button to acquire the target.
4. Click the **Close** button to exit the command.



Camera Drive: Use the Vantage's MultiView Cameras to acquire a target in the camera's field of view.

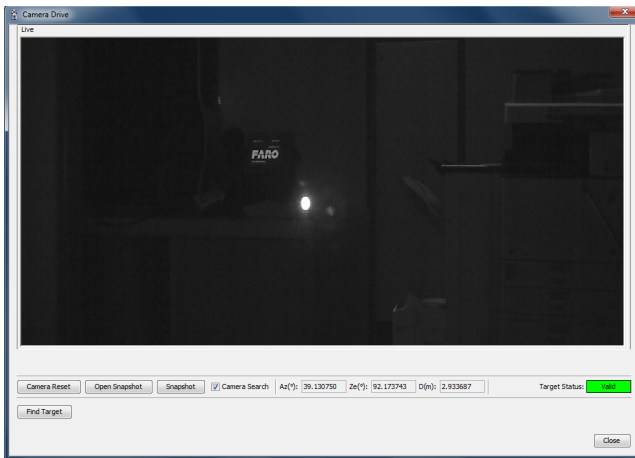


Figure 12-2 Camera Drive dialog box

NOTE: There is a distance limit to find targets with Camera Drive:

- 82ft (25M) with a 1.5” SMR
- 49ft (15M) with a 0.5” SMR

Camera Reset Button - resets the MultiView Cameras to current light conditions.

Camera Search check box - automatically runs a simple search for any visible target on every image after the Laser Tracker Measuring Head moves.

Target Status - shows the status of the laser beam and the target:

- Valid when the Laser Tracker Measuring Head is locked on a target with a valid beam and target position.
- No Target when the Laser Tracker Measuring Head is not locked on a target.

To use the Camera Drive option:

1. Look at the video image in the CAMERA DRIVE dialog box. Any visible target appears as a round white circle.
2. If you do not see any targets in the CAMERA DRIVE dialog box image, click the Top, Bottom, Left, or Right edge of the image to move the Laser Tracker Measuring Head in that direction.
3. When the CAMERA SEARCH check box is selected, the camera will do a simple search for any visible targets.

NOTE: To save time, clear the CAMERA SEARCH check box if you need to move the Laser Tracker Measuring Head more than one window length.

4. Click the **Find Target** button to run SmartFind if the camera search does not lock onto a target.
5. Click the **Close** button to exit the command.

The CAMERA DRIVE dialog box also contains the following buttons to create a snapshot, a saved visual location:

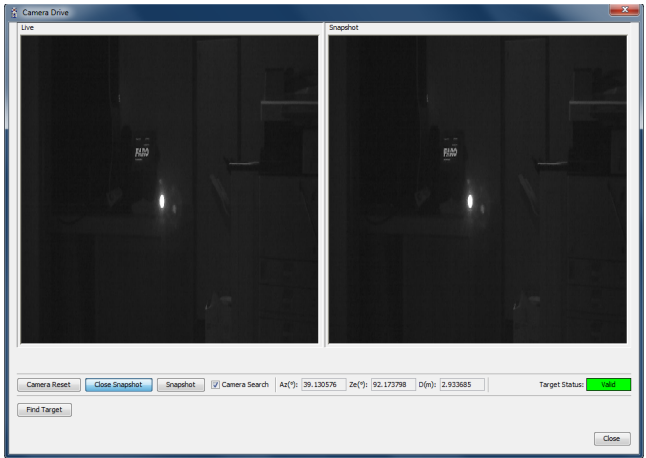


Figure 12-3 Snapshot

Open Snapshot - opens the SNAPSHOT window and saves the current image location. Click anywhere in the SNAPSHOT window to return to this location after moving the Laser Tracker Measuring Head.

Snapshot - updates the SNAPSHOT window with the current image.

Set Weather Configuration

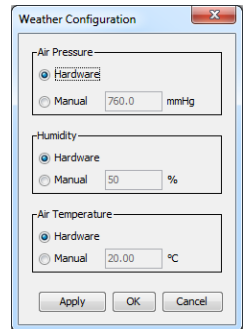
Select and configure the source for the weather information. The **HARDWARE** option uses the Vantage's integrated weather station. The **MANUAL** option uses the entered weather information.

CAUTION: Manually entering values that do not represent the current air properties can result in inaccurate measurements.

To manually enter weather information:

1. Click each **MANUAL** radio button.
2. Enter the weather information.
3. Click the **Apply** button to apply the changes, and then click **OK** to exit the command.

NOTE: Clicking the **Cancel** button before clicking the **Apply** button exits the command *without* making changes.



NOTE: All weather configuration settings will revert to HARDWARE if the Vantage is powered off.

Set Temperature Configuration

View and configure any temperature sensors connected to the MCU.

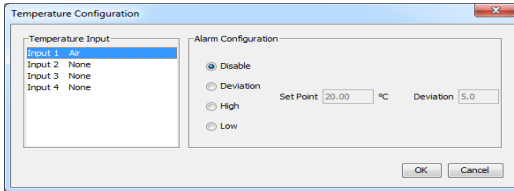


Figure 12-4 Temperature Sensor Configuration dialog box

Display Bubble Level

View the orientation of the Laser Tracker Measuring Head with respect to gravity.

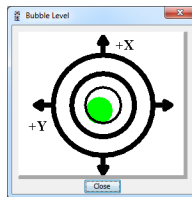


Figure 12-5 Temperature Sensor Configuration dialog box

Set Time

Set the Vantage's internal Date and Time.

Turn Gesture On/Off

Switch the Vantage's Smart Find gesture on and off. This is off by default. *For more information, see "SmartFind" on page 134.*

Turn Wireless On/Off

Switch the Vantage's Wireless communication on and off. This is off by default. *For more information, see "Wireless Connection" on page 37.*

Drive Beam

Click the **Drive Beam** button to move the FARO Laser Tracker Measuring Head's laser beam. *For more information, see “Drive Beam” on page 125.*

Motors

Click the **Motors** button to switch on or off the motors that control the movement of the laser beam. The text of this button will change as you switch the motors on or off.

Settings

Click the **Settings** button to edit some of the Vantage's settings.

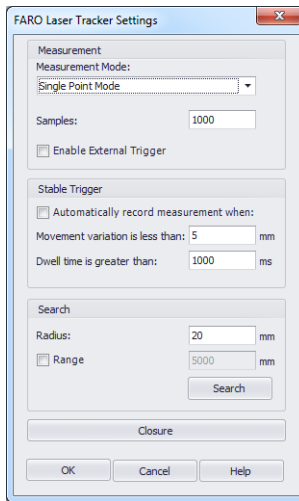


Figure 12-6 FARO Laser Tracker Settings dialog box

Measurement Mode

Choose a mode. The samples (individual laser measurements of the SMR position) are best fit into a single reading. The default is 1000 samples per reading.

- **Single Point Mode - Fixed Sampling:** Enter the number of samples. This mode uses all samples.
- **Distance Based Mode:** Enter the number of measurement samples for each reading and the distance between readings. A reading records as the SMR moves the distance.

- Time Based Mode: Enter the number of measurement samples for each reading and the time between readings. A reading records as time passes.

Stable Trigger

Use this to have the Vantage automatically record a reading when the SMR is in a stable location.

- Select the check box to switch on the Stable Trigger.
- Enter a distance.
- Enter a time.

Move the SMR to a location. When the SMR moves less than the distance the timer starts. After the SMR has remained stable for the time a single reading is added. You must move the SMR to another location greater than the distance for the trigger to reset.

Search

The size of the searching radius when the Vantage is automatically searching for an SMR. Select the RANGE check box to set a minimum and maximum search distance.

Closure

Click the **Closure** button to open the CLOSURE dialog box. The CLOSURE dialog box shows the distance from the target to the Home position. When the target is at the Home position, it should read approximately 0.000 mm. *It is intended to be used at the end of a group of Interferometer Only mode measurements to verify that Interferometer count loss did not occur.* With an ADM Only laser tracker such as the Vantage, it can be used to determine approximately how far the target is away from the Laser Tracker Measuring Head.

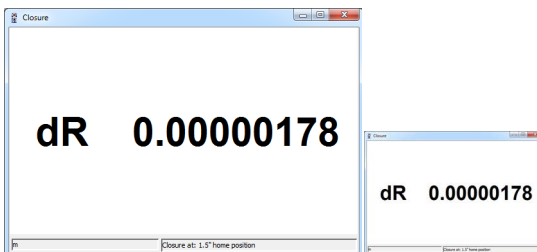


Figure 12-7 Closure Window

Environment Check

Click the **Environment Check** button to start the Operation Checks. *For more information, see “Operational Checks” on page 69.*

Disconnect

In the list of devices, select a Vantage and click the **Disconnect** button to disconnect it from CAM2 Measure. Use the **Add New Device** button to search for devices connected to your computer. *See “Add a Device” on page 122.*



Manage Devices

The **Manage Devices** command accesses the DEVICE MANAGER panel and configure the device properties of the Vantage. For more information, see the *Manage Devices* section of the *Devices* chapter in the CAM2 Measure manual.



Move Device

The **Move Device** command accesses the MOVE DEVICE POSITION wizard and perform measurements to move your Vantage around the part. You can also press the **M** hot key on the keyboard. For more information, see the *Manage Devices* section of the *Devices* chapter in the CAM2 Measure manual.

Tracker Group

The **Tracker** group in the **Devices** tab contains the most common commands necessary to interface with your Vantage using Tracker Utilities. For more information, see the *Tracker* section of the *Devices* chapter in the CAM2 Measure manual.

Survey

Survey is a Laser Tracker specific command in CAM2 Measure. Surveying is an automated, repetitive measurement process used to track the position(s) of one or more targets over time. The output is a statistical analysis of the change in positions for each target. Optionally, you can use the Survey command to automatically reposition a measurement device once you detect sufficient movement.

For more information, see the *Survey* section of the *Navigation Window* chapter in the CAM2 Measure manual.

Measuring with the Vantage

When measuring with an SMR ❶, the location of the center of the SMR records as a point each time you press the **G** key. Because each SMR has a known diameter, there is a known distance between the center of the SMR and the outer edge of the SMR. This distance needs to be specified (projected) for the point to record in the correct location.

The distance between the SMR point of contact ❷ with the surface being measured and the center of the SMR ❸ is known as SMR Offset ❹. This transfer of the point from the center of the SMR to the correct location is known as SMR compensation.

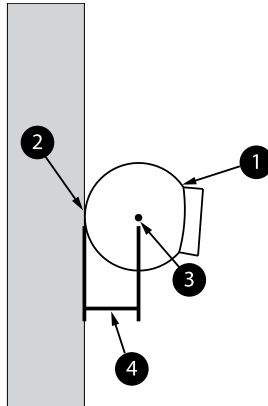


Figure 12-8 Measuring with the SMR

Adding Readings

Use commands to control the Vantage instead of hardware buttons. Buttons (and their associated hot keys) on the MEASUREMENT panel are used for recording a

reading (**G** key), recording an end click (**H** key), and removing the last reading (Backspace key). You can also click the icons in the MEASUREMENT panel.

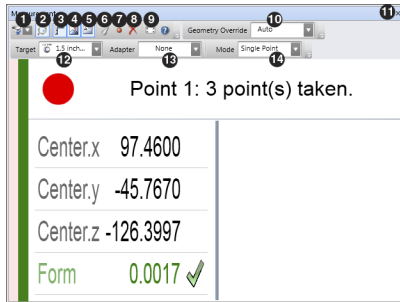





Figure 12-9 Measurement Panel

-  **Record Measurement**
-  **Record End Click**
-  **Remove Last Reading**

For more information, see the *Measurement Panel* section of the *Measure* chapter in the CAM2 Measure manual.

SmartFind

SmartFind is an internal routine that quickly and efficiently locates and locks on to the correct target. When you break or lose the laser beam while in MultiView Cameras field of view, you can simply gesture to the Vantage and it will aim the beam back to your target.

NOTE: There is a distance limit with SmartFind:

- 65ft (20M) with a 1.5” SMR
- 49ft (15M) with a 0.5” SMR

By default, the recognition of the gesture is disabled and the button to enable the gesture is located in the TrackerPad command. See “TrackerPad” on page 124. To use Smart Find:

1. Move your SMR into the MultiView Cameras field of view.



2. Perform the SmartFind gesture, move the SMR slowly to the left (roughly about 18in/0.5M) and then back to the original location.



NOTE: You can move the SMR in any direction and back to the original location.

3. If necessary, repeat this motion until the Blue Aperture Lights on the Laser Tracker Measuring Head turn on and start to blink quickly.



4. Hold the SMR still while the cameras locate and lock on to the SMR. The Amber Aperture Lights on the Laser Tracker Measuring Head turn on solid.



5. The laser beam locks on to the SMR. The Green Aperture Light on the Laser Tracker Measuring Head turn on solid.



NOTE: The MultiView cameras have a 30° field of view. If the SMR is very close to the Laser Tracker Measuring Head, the movement must be short. For example, 4 inches (10 centimeters) when the SMR is 3 feet (1 meter) from the Laser Tracker Measuring Head.

Technical Support

FARO Technologies, Inc. is committed to providing the best technical support to our customers. Our Service Policy is in *Appendix C: FARO Products Service Policy* of this manual. If you have any problem using one of our products, please follow these steps before contacting our Technical Support Team:

- Be sure to read the relevant sections of the documentation to find the help you need.
- Visit the FARO Customer Care area on the Web at www.faro.com to search our technical support database. This is available 24 hours a day 7 days a week.
- Document the problem you are experiencing. Be as specific as you can. The more information you have, the easier the problem will be to solve.
- If you still cannot resolve your problem, have your device's Serial Number available *before calling*.

Support Hours (Monday through Friday)

North America:

8:00 a.m. to 7:00 p.m. Eastern Standard Time (EST).

Europe:

8:00 a.m. to 5:00 p.m. Central European Standard Time (CET).

Asia:

8:30 a.m. to 5:30 p.m. Singapore Standard Time (SST).

Japan:

9:00 a.m. to 5:00 p.m. Japan Standard Time (JST).

China:

8:30 a.m. to 5:30 p.m. China Standard Time (CST).

India:

9:30 a.m. to 5:30 p.m. India Standard Time (IST).

You can also e-mail or fax any problems or questions 24 hours a day.

Phone

North America:

800 736 2771, +1 407 333 3182 (Worldwide)

Mexico:

001-866-874-1154

Europe:

+800 3276 7378, +49 7150 9797-400 (Worldwide)

Asia:

1800 511 1360, +65 6511 1350 (Worldwide)

Japan:

0120.922.927, +81 561 63 1411 (Worldwide)

China:

400.677.6826, +86 21 6191 7600 (Worldwide)

India:

1800.1028456, +91-1146465656 (Worldwide)

Thailand:

+662.7441273-6 (Worldwide)

Korea:

+82.51.662.3413 (Worldwide)

Fax

North America:

+1 407 562 5294

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+800 3276 1737, +49 7150 9797-9400 (Worldwide)

Asia:

65 65430111

Japan:

+81 561 63 1412

China:

+86 021 61917600

India:

+91-11-46465660

Thailand:

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supportindia@faro.com

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Korea:

supportkorea@faro.com

E-Mails or Faxes sent outside regular working hours usually are answered before 12:00 p.m. the next working day. Should our staff be on other calls, please leave a voice mail message; calls are always returned within 4 hours. Please remember to leave a description of your question and your device's Serial Number. Do not forget to include your name, fax number, telephone number and extension so we can reach you promptly.

Appendix A: Software License Agreement

This Software License Agreement is part of the Operating Manual for the product and software System which you have purchased from FARO TECHNOLOGIES, INC. (collectively, the “Licensor”) By your use of the software you are agreeing to the terms and conditions of this Software License Agreement. Throughout this Software License Agreement, the term “Licensee” means the owner of the System.

I. The Licensor hereby grants the Licensee the non-exclusive right to use the computer software described in this Operating Manual (the “software”). The Licensee shall have no right to sell, assign, sublicense, rent or lease the software to any third party without the Licensor’s prior written consent.

II. The Licensor further grants the Licensee the right to make a backup copy of the software media. The Licensee agrees that it will not decompile, disassemble, reverse engineer, copy, transfer, or otherwise use the software except as permitted by this section. The Licensee further agrees not to copy any written materials accompanying the software.

III. The Licensee is licensed to use the Software only in the manner described in the Operating Manual. Use of the Software in a manner other than that described in the Operating Manual or use of the software in conjunction with any non-Licensor product which decompiles or recompiles the software or in any other way modifies the structure, sequence or function of the software code, is not an authorized use, and further, such use voids the Licensor’s set forth below.

IV. The only warranty with respect to the software and the accompanying written materials is the warranty, if any, set forth in the Quotation/Purchase Order and *Appendix B: Purchase Conditions* pursuant to which the software was purchased from the Licensor.

V. THIS WARRANTY IS IN LIEU OF OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE SOFTWARE AND WRITTEN MATERIALS. IN NO EVENT WILL THE LICENSOR BE LIABLE FOR DAMAGES, INCLUDING ANY LOST PROFITS OR OTHER INCIDENTAL OR

CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OR INABILITY TO USE THE SOFTWARE, NOTWITHSTANDING THAT THE LICENSER HAVE BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, THE LICENSER WILL NOT BE LIABLE FOR ANY SUCH CLAIM BY ANY OTHER PARTY.

VI. In the event of any breach by the Licensee of this Agreement, the license granted hereby shall immediately terminate and the Licensee shall return the software media and all written materials, together with any copy of such media or materials, and the Licensee shall keep no copies of such items.

VII. The interpretation of this Agreement shall be governed by the following provisions:

A. This Agreement shall be construed pursuant to and governed by the substantive laws of the State of Florida (and any provision of Florida law shall not apply if the law of a state or jurisdiction other than Florida would otherwise apply).

B. If any provision of this Agreement is determined by a court of competent jurisdiction to be void and non-enforceable, such determination shall not affect any other provision of this Agreement, and the remaining provisions of this Agreement shall remain in full force and effect. If any provision or term of this Agreement is susceptible to two or more constructions or interpretations, one or more of which would render the provision or term void or non-enforceable, the parties agree that a construction or interpretation which renders the term of provision valid shall be favored.

C. This Agreement constitutes the entire Agreement, and supersedes all prior agreements and understandings, oral and written, among the parties to this Agreement with respect to the subject matter hereof.

VIII. If a party engages the services of an attorney or any other third party or in any way initiates legal action to enforce its rights under this Agreement, the prevailing party shall be entitled to recover all reasonable costs and expenses (including reasonable attorney's fees before trial and in appellate proceedings).

Appendix B: Purchase Conditions

All Purchase Orders (hereafter, the “Order”) for FARO-provided products and services (hereafter, the “Product”) are subject to the following terms and conditions, which are agreed to by the Purchaser. All capitalized terms are defined in Section 8.00 Definitions hereafter.

1.00 Payment of Purchase Price

1.01 Purchaser hereby promises to pay to the order of FARO all deferred portions of the Purchase Price, together with interest on late purchase price payments payable at 1.5% per month (18% per annum).

1.02 The Purchaser grants to FARO a security interest in the products sold pursuant to the Order, which may be perfected by UCC-1 Financing Statements to be recorded in the applicable County of the Purchaser’s business location and filed with the Secretary of State’s Office, which security interest will remain in effect until payment in full of the purchase price together with interest on late purchase price payments payable thereon had been received by FARO.

1.03 If the Purchaser fails to make full payment of the purchase price within the period set out in the Order, FARO shall at its option have the following remedies, which shall be cumulative and not alternative:

- a) the right to cancel the Order and enter the Purchaser’s premises to re-take possession of the Product, in which event the Purchaser agrees that any down-payment or deposit shall be forfeited to FARO, as liquidated damages and not as a penalty, and all costs incurred by FARO in connection with the removal and subsequent transportation of the Product shall be payable by the Purchaser upon written demand;
- b) the right to enter the Purchaser’s premises and remove any Software, components of the Product or other items necessary in order to render the Product inoperative;
- c) the right to withhold all services which would otherwise be required to be provided by FARO pursuant to the Warranties set out in Section 4.00 Warranties and Limitation of Liability hereof;
- d) terminate any existing software license agreement and
- e) pursue any other available remedy, including suing to collect any remaining balance of the purchase price (i.e., accelerate the

payment of the purchase price causing the entire balance to immediately become due and payable in full).

f) Customer will be charged a 20% restocking fee for refusal to accept equipment as delivered. Equipment must be returned unopened within 10 business days of receipt at customer facility.

1.04 If Purchaser fails to make payment(s) in accordance with the terms of this Order, the Purchaser's Products may be rendered inoperable until such payment terms are met.

No waiver by FARO of its rights under these conditions shall be deemed to constitute a waiver of subsequent breaches or defaults by the Purchaser. In the event more than one Product is being purchased pursuant to the Order, unless otherwise set forth herein, each payment received by FARO from Purchaser shall be applied pro rata against the cost of each product rather than being applied to the purchase price of any product.

2.00 Delivery and Transportation

2.01 Delivery dates are estimates and not guarantees, and are based upon conditions at the time such estimate is given.

2.02 FARO shall not be liable for any loss or damage, whether direct, indirect or consequential, resulting from late delivery of the Product. The Purchaser's sole remedy, if the Product is not delivered within 90 days of the estimated delivery date, shall be to cancel the Order and to recover from FARO without interest or penalty, the amount of the down-payment or deposit and any other part of the purchase price which has been paid by the Purchaser. Notwithstanding the foregoing, such right of cancellation shall not extend to situations where late delivery is occasioned by causes beyond FARO's control, including, without limitation, compliance with any rules, regulations, orders or instructions of any federal, state, county, municipal or other government or any department or agency thereof, force majeure, acts or omissions of the Purchaser, acts of civil or military authorities, embargoes, war or insurrection, labor interruption through strike or walkout, transportation delays and other inability resulting from causes beyond FARO's control to obtain necessary labor, manufacturing facilities or materials from its usual sources. Any delays resulting from such causes shall extend estimated delivery dates by the length of such delay.

2.03 Responsibility for all costs and risks in any way connected with the storage, transportation and installation of the Product shall be

borne entirely by the Purchaser. If any disagreement arises as to whether or not damage to the Product was in fact caused in storage, transit or on installation, the opinion of FARO's technical advisors, acting reasonably, shall be conclusive.

3.00 Installation and Operator Training

3.01 The Purchaser shall be responsible for installation of the Product, including, without limitation, the preparation of its premises, the uncrating of the Product and setting up of the Product for operation. Purchaser may elect to order contract services from FARO to perform this service should they elect to do so.

4.00 Warranties and Limitation of Liability

4.01 FARO warrants that (subject to Section 4.06), the Product shall be free from defects in workmanship or material affecting the fitness of the Product for its usual purpose under normal conditions of use, service and maintenance. A complete statement of FARO's maintenance/warranty service is set forth in *Appendix C: FARO Products Service Policy*.

4.02 FARO warrants that the Software shall operate according to specifications and the System shall operate and perform in the manner contemplated in connection with the usual purpose for which it is designed.

4.03 The maintenance/warranty set out in paragraphs 4.01 shall expire at the end of the twelve (12) month period commencing on the date of shipment from the FARO factory (the "Maintenance/Warranty Period").

4.04 Subject to the limitations contained in Section 4.06, the Warranties shall apply to any defects found by the Purchaser in the operation of the Vantage and reported to FARO within the Maintenance/Warranty Period. If the Vantage or the Software is found by FARO, acting reasonably, to be defective, and if the defect is acknowledged by FARO to be the result of FARO's faulty material or workmanship, the Vantage will be repaired or adjusted to the extent found by FARO to be necessary or at the option of FARO, replaced with a new Vantage or parts thereof at no cost to the Purchaser.

4.05 Claims under the Warranties shall be made by delivering written notice to FARO of the defect in the System, the Vantage. Within a reasonable time of receipt of such notice, FARO shall have the System and Vantage diagnosed by its service personnel, and maintenance/

warranty service will be provided at no cost to the Purchaser if the System and Vantage is found by FARO to be defective within the meaning of this Section.

(If, in the reasonable opinion of FARO after diagnosis of the system and the Vantage are not defective, the Purchaser shall pay the cost of service, which shall be the amount that FARO would otherwise charge for an evaluation under a non-warranty service evaluation.

4.06 The Warranties do not apply to:

- a) Any defects in any component of a System where, if in the reasonable opinion of FARO, the Vantage, Software or System has been improperly stored, installed, operated, or maintained, or if Purchaser has permitted unauthorized modifications, additions, adjustments and/or repair to any hard drive structure or content, or any other part of the System, or which might affect the System, or defects caused or repairs required as a result of causes external to FARO workmanship or the materials used by FARO. As used herein, “unauthorized” means that which has not been approved and permitted by FARO.
- b) The Warranties shall not cover replacement of expendable items, including, but not limited to, fuses, diskettes, printer paper, printer ink, printing heads, disk cleaning materials, or similar items.
- c) The Warranties shall not cover minor preventive and corrective maintenance, including, but not limited to, replacement of fuses, disk drive head cleaning, fan filter cleaning and system clock battery replacement.
- d) Any equipment or its components which was sold or transferred to any party other than the original Purchaser without the expressed written consent of FARO.

4.07 Factory Repairs

- a) IF SYSTEM IS UNDER MAINTANENCE/WARRANTY: The Purchaser agrees to ship the Product to FARO in the original packing containers. FARO will return the repaired or replacement Product. FARO will incur the expense of the needed part and all return shipping charges to the Purchaser. FARO may authorize the manufacturer of a component of the Product to perform the service.
- b) IF SYSTEM IS UNDER PREMIUM SERVICE PLAN: When practical and subject to availability, FARO will make available to

the Purchaser substitute component parts or Vantage's ("Temporary Replacements") while corresponding parts of the Purchaser's system or Vantage are undergoing repair at FARO's factory. Shipping charges for these "Temporary Replacement" parts or Vantage's will be the responsibility of FARO.

c) IF SYSTEM IS NOT UNDER MAINTANENCE/ WARRANTY: The Purchaser is responsible for the cost of the replacement part or software, and all shipping charges. All charges shall be estimated and prepaid prior to commencement of repairs.

d) Replacement parts used for repair may be new, refurbished, or contain refurbished materials.

4.08 Nothing herein contained shall be construed as obligating FARO to make service, parts, or repairs for any product available after the expiration of the Maintenance/Warranty Period.

4.09 Limitation of Liability

FARO shall not be responsible under any circumstances for special, incidental or consequential damages, including, but not limited to, injury to or death of any operator or other person, damage or loss resulting from inability to use the System, increased operating costs, loss of production, loss of anticipated profits, damage to property, or other special, incidental or consequential damages of any nature arising from any cause whatsoever whether based in contract, tort (including negligence), or any other theory of law. FARO's only liability hereunder, arising from any cause whatsoever, whether based in contract, tort (including negligence) or any other theory of law, consists of the obligation to repair or replace defective components in the System or Vantage subject to the limitations set out above in this section.

This disclaimer of liability for consequential damage extends to any such special, incidental or consequential damages which may be suffered by third parties, either caused directly or indirectly resulting from test results or data produced by the system or any component thereof and the Purchaser agrees to indemnify and save FARO harmless from any such claims made by third parties.

4.10 The foregoing shall be FARO's sole and exclusive liability and the Purchaser's sole and exclusive remedy with respect to the system.

THE SOLE RESPONSIBILITY OF FARO UNDER THE WARRANTIES IS STATED HEREIN AND FARO SHALL NOT BE

LIABLE FOR CONSEQUENTIAL, INDIRECT, OR INCIDENTAL DAMAGES, WHETHER THE CLAIM IS FOR BREACH OF WARRANTY, NEGLIGENCE, OR OTHERWISE.

OTHER THAN THE EXPRESS WARRANTIES HEREIN STATED, FARO DISCLAIMS ALL WARRANTIES INCLUDING IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS.

4.11 FARO does not authorize any person (whether natural or corporate) to assume for FARO any liability in connection with or with respect to the Products. No agent or employee of FARO has any authority to make any representation or promise on behalf of FARO, except as expressly set forth herein, or to modify the terms or limitations of the Warranties. Verbal statements are not binding upon FARO.

4.12 The Maintenance/Warranties extend only to the Purchaser and are transferable, only under the following conditions:

- The Vantage is currently under maintenance/warranty.
- New owner is, or becomes, a certified user.
- A FARO maintenance/warranty transfer form is completed, and submitted to Customer Service.

All claims under the Warranties must originate with the Purchaser, or any subsequent owner, and the Purchaser will indemnify and save FARO harmless from any claims for breach of warranty asserted against FARO by any third party.

4.13 Oral representations of FARO or its sales representatives, officers, employees or agents cannot be relied upon as correctly stating the representations of FARO in connection with the system. Refer to this purchase order, any exhibits hereto and any written materials supplied by FARO for correct representations.

4.14 PURCHASER ACKNOWLEDGES THAT IT HAS PURCHASED THE SYSTEM BASED UPON ITS OWN KNOWLEDGE OF THE USES TO WHICH THE SYSTEM WILL BE PUT. FARO SPECIFICALLY DISCLAIMS ANY WARRANTY OR LIABILITY RELATED TO THE FITNESS OF THE SYSTEM FOR ANY PARTICULAR PURPOSE OR ARISING FROM THE INABILITY OF THE PURCHASER TO USE THE SYSTEM FOR ANY PARTICULAR PURPOSE.

5.00 Design Changes

5.01 The Vantage, the Software and the System are subject to changes in design, manufacture and programming between the date of order and the actual delivery date. FARO reserves the right to implement such changes without the Purchaser's consent, however, nothing contained herein shall be construed as obligating FARO to include such changes in the Vantage, Software or System provided to the Purchaser.

6.00 Non-Disclosure

6.01 All Software including, without limitation, the Operating System Program and any FARO special user programs, provided to the Purchaser as part of the system, either at the time of or subsequent to the delivery of the Vantage, is the intellectual property of FARO. The Purchaser shall not reproduce or duplicate, disassemble, decompile, reverse engineer, sell, transfer or assign, in any manner the Software or permit access to or use thereof by any third party. The Purchaser shall forthwith execute any further assurances in the form of non-disclosure or licensing agreements which may reasonably be required by FARO in connection with the software.

7.00 Entire Agreement / Governing Law / Miscellaneous / Guarantee

7.01 These Purchase conditions constitute the entire agreement between FARO and the Purchaser in respect to the Product. There are no representations or warranties by FARO, express or implied, except for those herein contained and these conditions supersede and replace any prior agreements between FARO and the Purchaser.

7.02 No representative of FARO has any authority to modify, alter, delete or add to any of the terms or conditions hereof. Any such modifications shall be absolutely void unless made by instrument in writing properly executed by an actual authorized employee or agent of FARO.

7.03 The terms and conditions hereof shall be binding upon FARO and the Purchaser, and shall be construed in accordance with the laws of the State of Florida, United States of America.

7.04 FARO shall be entitled to recover all of its reasonable fees and costs including, but not limited to, its reasonable attorney's fees incurred by FARO in connection with any dispute or litigation arising thereunder or in connection herewith, including appeals and bankruptcy or creditor reorganization proceeds.

7.05 These conditions shall not be construed more strictly against one party than another as a result of one party having drafted said instrument.

8.00 Definitions

8.01 “FARO” means FARO Technologies, Inc.

8.02 “Purchaser” means the party buying the Product and who is legally obligated hereunder.

8.03 “Software” means all computer programs, disk drive directory organization and content, including the computer media containing such computer programs and disk drive directory organization and content, sold pursuant to the Order.

8.04 “Product” means the Vantage, the Software, operating manuals and any other product or merchandise sold pursuant to the Order. If the Purchaser is buying only a Vantage, or the Software, Product will mean the product being purchased by the Purchaser pursuant to the Order.

8.05 “System” means a combination of the Vantage, the Software, the Computer, and optional parts and accessories associated with the Vantage.

8.06 “Certified user” means any person who has completed and passed the written exam issued by FARO. The exam is available upon request.

8.07 “Purchase Order” means the original document issued from the Purchaser to FARO, listing all parts and/or services to be purchased and the agreed purchase price.

8.08 “Maintenance/Warranty Transfer Form” means a document to be completed for the transfer of the FARO Maintenance/Warranty. This document is available from FARO upon request.

Appendix C: FARO Products Service Policy

A one-year maintenance/warranty comes with the purchase of new FARO-manufactured hardware products. Supplemental Service Plans are also available at additional cost. See *Appendix D: FARO Service Policy* for further details.

FARO Hardware under Maintenance/Warranty

The following is a summary of what services can be obtained under the original warranty or Supplemental Service Plan.

1. Factory repairs on FARO-manufactured hardware products at any FARO Service Center.
2. Factory repairs are targeted for completion within 7 (FaroArms and Laser Line Probe), 14 (Laser Trackers and Laser Scanners), or 10 (3D Imagers) working days of FARO's receipt of the defective item. The customer is responsible for returning the hardware to a FARO Service Center in the original packing container or custom case.
3. FARO will return the hardware via 2-day service within the continental United States. Outside the continental United States, FARO will return the hardware to the customs broker via 2-day service. Expedited service can be arranged at the customer's expense.
4. Upon expiration of the original warranty, a Supplemental Service Plan may be purchased and renewed on an annual basis for any FARO-manufactured hardware products, as long as material and resources are available.
5. All Supplemental Service Plans will be due for renewal one year and one day from the day the FARO-manufactured hardware is shipped from FARO.
6. Please contact FARO Customer Service to transfer the warranty. The original warranty and Supplemental Service Plans are transferable to subsequent owners under the following conditions:

- The Hardware Device is currently under the original warranty and Supplemental Service Plan.
- The new owner is, or becomes, a certified user.
- FARO Customer Service is informed of and approves the transfer.

Upon approval by FARO Customer Service, the new owner will receive a FARO Transfer of Original Warranty or Service Plan agreement form executed by FARO.

7. Replacement parts used for repair may be new, refurbished, or contain refurbished materials.

FARO Hardware NOT under Maintenance/Warranty

Factory assessments and repairs on FARO-manufactured products will follow the following procedure:

1. The customer obtains a service number from FARO's Customer Service Department.
2. The customer ships the product to a FARO Service Center with the service number on the label along with payment or a corporate purchase order for system testing and evaluation, which includes compensation and calibration.
3. The payment will be applied toward the total service cost beyond the initial payment. The estimated repair cost will be given to the customer prior to the repair. The total cost must be paid prior to beginning the service.
4. The customer is responsible for all shipping charges to and from FARO, including import and export fees for international customers.
5. FARO will continue to repair FARO-manufactured hardware products as long as material and resources are available.
6. Replacement parts used for repair may be new, refurbished, or contain refurbished materials.

FARO Software

FARO's warranty may differ depending on the Software you are utilizing. Please consult your software warranty or contact FARO

customer service to determine the warranty conditions for your particular software.

Hardware & Software Training

FARO's training program is designed to instruct trainees in the operation of FARO's hardware and software, which the customer has purchased. The training classes are set up for each trainee to obtain valuable hands on application exposure. This will help the trainees in their everyday use of the hardware and software. FARO also feels that once the trainee completes the training, finding solutions to problems or applying applications will be simpler. Details are as follows:

1. The training class will prepare attendees to successfully attain an operator's certification (see *Certification Requirements* section below for more details).
2. The fee schedules for advanced additional training courses can be obtained from Customer Service, or the Sales department.

Certification Requirements

An operator's inherent ability to understand 3D concepts may be in their background training. However, the precision with which the operator performs 3D measurements with the Hardware Device is critical in establishing the accuracy and repeatability of the results of subsequent measurements.

In order to establish the proficiency of operators, FARO has instituted an Operator Certification program, wherein each operator's knowledge and understanding of the Hardware Device is evaluated. The successful operator is awarded a certificate which identifies him/her as an accredited operator of the product. The requirements are as follows:

1. Attend a FARO-conducted basic training course, either at a FARO Facility or on site at your facility.
2. Certification will be awarded once the class has been completed, and then the certified user will be registered for hardware and software support.

To certify an operator, please contact your local FARO office.

Repair Fee Schedule

(Out of Warranty/Maintenance Owners Only!)

System Testing and Evaluation Fee - Contact your local FARO Service Center for pricing.

A fee is charged for any system testing and evaluation. This includes system diagnosis, compensation and calibration, and applies to all FARO-manufactured hardware. However, this fee does not include disassembly/repair costs if required. An estimated cost for disassembly/repair will be given to the customer prior to the repair. The disassembly/repair charges must be paid in full prior to the actual disassembly/repair. However, if no repairs are needed the fee will be applied to the cost of system testing and evaluation. All evaluations contain a calibration. Recertification will be performed on an “as needed” basis.

Contact your local FARO Service Center for the current system testing and evaluation fee pricing.

Transfer of Original Warranty or Service Plan Agreement

(SELLER'S CORPORATE, BUSINESS UNIT, OR INDIVIDUAL NAME AS APPLICABLE),
hereby waives all rights under the warranty service policy for:

Hardware Device Serial Number _____
Additional Hardware Device Serial Number _____
Computer Service Tag Number _____
purchased originally on _____ (DATE).

(BUYER'S CORPORATE, BUSINESS UNIT, OR INDIVIDUAL NAME AS APPLICABLE),
hereby assumes all rights and obligations of the Hardware Warranty/Maintenance from
_____ (DATE OF TRANSFER).

This transfer is only valid under the following conditions:

1. The Hardware Device is currently under warranty/maintenance.
2. New owner is, or becomes, a certified user.
3. This maintenance/warranty transfer form is completed and submitted to FARO Customer Service.

AGREED

| | |
|--|---|
| _____ (PRINT SELLER'S CORPORATE, BUSINESS UNIT, OR INDIVIDUAL NAME AS APPLICABLE) | _____ (PRINT BUYER'S CORPORATE, BUSINESS UNIT, OR INDIVIDUAL NAME AS APPLICABLE) |
| X _____ | X _____ |
| _____ (PRINT NAME OF SIGNATORY) | _____ (PRINT NAME OF SIGNATORY) |

FARO Technologies, Inc.

Approved by X _____

(PRINT NAME OF SIGNATORY)

Buyer's Contact Information:

Company _____
Address _____
Address _____
City _____ State _____ Zip _____
Phone Number _____ E-mail _____

Appendix D: FARO Service Policy

This Service Plan (hereinafter, the “Plan”) is part of the Operating Manual for the FARO manufactured product purchased from FARO TECHNOLOGIES, INC. (hereafter, “FARO”). The Plan and all of the optional additions, are subject to the conditions in Appendices A, B, & C, and are subject to change at any time. This appendix refers to FARO’s service plans as written in the sales advertising literature, and is meant to provide additional details that the literature does not provide.

1.00 The purchase of the Plan shall occur with the purchase of the FARO products.

1.01 The Plan shall apply to systems exclusively created or authored by FARO.

1.02 The Plan shall include FARO product hardware only, and cannot be extended or transferred through the sale of any part of the system to a third party unless the entire system has been sold or transferred.

1.03 The Plan shall not cover Hardware or Software which has been subjected to misuse or intentional damage. FARO reserves the right to determine the condition of all returned Hardware and/or Software.

1.04 FARO shall determine the service method and contractor to service/repair all hardware which is not directly manufactured by FARO. All outside contractor terms and conditions are available from FARO and are incorporated herein by reference.

1.05 FARO shall not be responsible for any non-FARO authored software which inhibits the operation of the system. Furthermore the Plan will not cover the re-installation of any software.

1.06 The Hardware and Software are subject to changes in design, manufacture, and programming. All updates are as follows:

- a) Hardware - The Hardware Device and all of the associated optional parts, including the Computer, are not subject to updates.
- b) Software - All computer programs, authored by FARO, which are used in conjunction with the FARO provided Hardware, will be updated in accordance with a particular update plan specific to the software.

c) 3rd Party software - All computer programs not authored by FARO will not be updated under the Plan. The purchaser is responsible for the acquisition of all 3rd party software updates and warranty service or claims.

1.07 In the event that FARO replaces any product or replacement product, FARO retains all right, title, and interest in and to all products or portions of products that were replaced by FARO.

2.00 Definitions

2.01 “FARO” means FARO Technologies, Inc.

2.02 “Purchaser” means the party buying the Product and who is legally obligated hereunder.

2.03 “Product” means the FARO-manufactured Hardware Device, the Software, operating manuals and any other product or merchandise sold pursuant to the Order. If the Purchaser is buying only the FARO-manufactured Hardware Device, or the Software, Product will mean the product being purchased by the Purchaser pursuant to the Order.

2.04 “System” means a combination of the FARO-manufactured Hardware Device, optional parts associated therewith, the Software, and the Computer.

2.05 “Hardware” means the FARO-manufactured product and all associated optional parts, and the Computer if provided by FARO.

2.06 “Software” means all computer programs, authored by FARO, which are used in conjunction with the FARO provided Hardware.

The following is a layman’s definition of the coverage.

Standard Service Plans

All shipping times below are to destinations within the continental United States. Outside the continental U.S., FARO will ship equipment directly to the customs broker.

- Standard Service Plans are contracted at time of purchase or at any time while a unit is covered by a FARO hardware service plan (as described in more detail later).
- The Standard Service Plan covers the Product.
- Shipping costs, including insurance from the Purchaser to FARO are the responsibility of the Purchaser. FARO will be responsible for all return shipping costs including insurance.

- FARO will return the hardware via 2 day service within the continental United States.
- Outside the continental United States, FARO will return the hardware to the customs broker via 2 day service.
- Expedited service can be arranged at the customer's expense.
- All reasonable efforts will be made to keep the service repair time within 7 (FaroArm), or 14 (Laser Tracker and Laser Scanner) working days. The equipment will be returned via 2-Day service; therefore, total service repair time will vary due to return shipping location.
- As the Product may be used with software packages not authored by FARO, this service plan is limited to covering only FARO produced or authored products. For items not produced or authored by FARO, the customer is responsible for securing their own separate warranty or service plan coverage.

Hardware Coverage

Product minus Computer

Covered

- All parts and labor for the Product falling under normal use as described in Appendix B.
- Annual compensation and calibration of the Product as necessary.

Not Covered

- Misuse
- Intentional Damage
- Wear and tear of probes, SMRs, target tooling and adaptors, ball bars, auxiliary hardware products such as cables, wrenches, hex keys, screwdrivers, etc.

Computer

Covered

- FARO contracts with 3rd party service providers for this service for up to 3 years. The terms and conditions of FARO's contract with the provider apply herein and are incorporated herein by reference.
- Typically, these services include repair of the computer, memory cards, and video monitors.

Not Covered

- All exclusions contained in the 3rd party service provider's policy which is incorporated herein by reference.
- Software operating system installation.
- User intentional or unintentional removal of key software property or files.

Software Coverage

Covered

- FARO's warranty may differ depending on the Software you are utilizing. Please consult your software warranty or contact FARO customer service to determine the warranty conditions for your particular software.

Not Covered

- End users are responsible for the procurement and installation of 3rd party authored or software updates as required to use with FARO authored software products, unless FARO resold these packages to the end user as an authorized reseller. Examples of 3rd party authored software are: DOS, Windows, AutoCAD, AutoSurf, SurfCAM and others.

Extended Warranty with Loaner

The Extended Warranty with Loaner Plans additionally provide loaner equipment when service (and in some cases calibration) is required. All equipment shipping costs are paid for by FARO (both ways)¹. FARO will make its best efforts to ship all loaner equipment within 24 hours of the receipt of the purchaser's request. Once the need for a service has been verified by FARO, FARO will make its best effort to ship all loaner computers within 72 hours of the receipt of the purchaser's request.

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Abbreviations/Acronym

- ADM (Absolute Distance Meter)
- ASME (American Society of Mechanical Engineers)
- MCU (Master Control Unit)
- MPE (Maximum Permissible Error)
- NIST (National Institute of Standards and Technology)
- SMR (Spherically Mounted Retroreflector)
- TCP/IP (Transmission Control Protocol/Internet Protocol)
- TMR (Tracker Mounted Reset)
- UPS (Uninterruptible Power Supply)
- WEEE (Waste Electrical and Electronic Equipment)

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