FARO® Laser Tracker ION™

Manual

April 2016

FARO®

FARO Technologies Inc. Internal Control File Locations:
\CONTROL\REFERENC\08PRODUC\ENGLISH\Prdpub62\08m62e00 - FARO Laser Tracker ION - April 2016.pdf
\FARO Tracker Doc Control\RECORDS\05 Production\PARTSPEC\922-03848 Rev. D - ION User Manual - April 2016 - English.pdf

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Chapter 1: Introduction

Thank you for choosing the FARO Laser Tracker ION. This introduction contains information on how to reach FARO, how to read the manual, and a brief overview of the ION. Additional information about accessories and important guidelines on maintaining your new ION is also included. 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 129.*

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.

ALL CAPITAL text	Indicates directory names, menu names, buttons, tabs, key names, acronyms, and modes.
`monospaced` text	Indicates alpha/numeric characters or values you enter in a field on the screen. For example, "Type `0.005` for the tolerance setting."
bold text	Anything you must enter exactly as it appears on your keyboard. For example, to type **a:install**, you would see text in bold type exactly as it should be entered.
SMALL CAPS text	Indicates dialogue box, icon names, and window names.

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 *measure* 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, *click* OK to open the file" or "*Press* 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 the like 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 the like 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 ION System is a portable, high accuracy, three-dimensional coordinate measurement device which has a measurement range of up to 180 feet (55 m) with designated long range targets. The Laser Tracker 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 30 feet (9.2 m) from the Laser Tracker Measuring Head.

The Laser Tracker Measuring Head emits an eye safe laser that is reflected off a Retroreflector target, typically a Spherically Mounted Retroreflector (SMR), 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.

A fully-integrated weather station is standard with every ION system to ensure accurate distance measurement. A precision level sensor is also included inside

the Laser Tracker Measuring Head allowing accurate measurement of the gravity vector.

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 tracker. For security purposes, this memory does not store tracker measurements and cannot be used to transfer information from one computer to another.

IFM Standard Model

When equipped with the standard fringe counting interferometer (IFM), the Laser Tracker Measuring Head emits a stabilized red helium neon laser that is used for the interferometer to measure the radial distance to the target. The standard model Interferometer system can improve slightly on the overall accuracy of the Laser Tracker but cannot re-acquire the beam in mid-air and requires going resetting the beam upon a beam break.

FARO Laser Tracker ION Base Special Order (ADM Only)

The ION ADM Only model measures the radial distance to the target using a phase shift Absolute Distance Meter (ADM) system named AgileADM™. The AgileADM 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 ION ADM Only model also has an instant-on laser and is ready to work immediately after power up.

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 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.

WEEE Symbol

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

Chapter 2: FARO Laser Tracker ION Safety

The ION outputs a visible red laser beam. The source of the red light is a Helium Neon (HeNe) laser (standard model IFM), or an instant-on pointer beam (ION special order ADM only model), which have an output of 1 milliwatt max/cw and are 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 IONs also have an ADM beam, which 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 CPR parts 1000 and 1040, and those of the international standard IEC EN 60825-1 2001-08.

The ION 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 front 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.

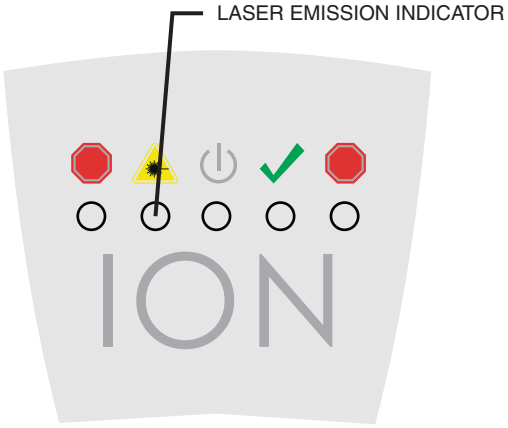


Figure 2-3 Laser Emission Indicator

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.

The top portion is the working logotype, which is required on all Class II laser products. It contains the wording:

LASER RADIATION, DO NOT STARE INTO BEAM.
633-635 nm Laser, 1 milliwatt max/cw.
CLASS II LASER PRODUCT.

Underneath 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.

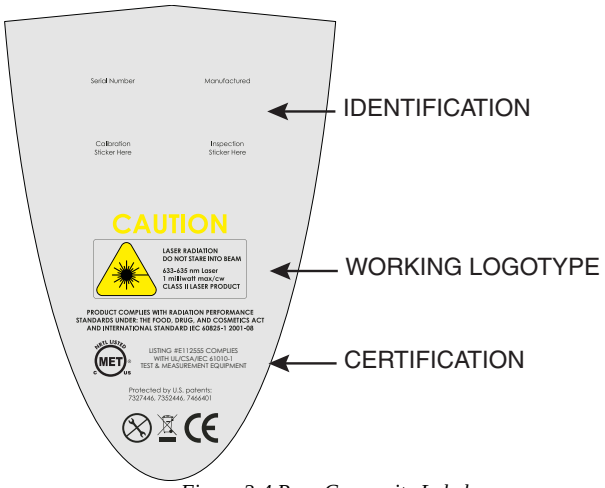


Figure 2-4 Rear Composite Label

Lifting the Laser Tracker Measuring Head

A safety label is located on the rear of the Laser Tracker Measuring Head above the rear lifting handle. Follow safe lifting procedures when removing the Laser Tracker Measuring Head from its shipping containers. Always use safe lifting procedures when placing the Laser Tracker Measuring Head on, or removing the Laser Tracker Measuring Head from, the instrument stand. See Figure 2-5 for the location of the safety label.

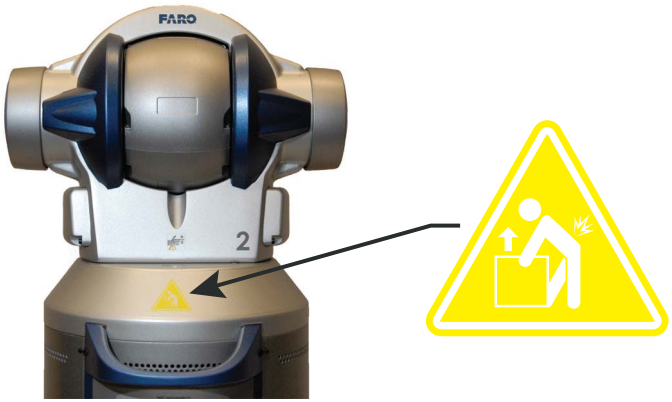


Figure 2-5 Lifting Label

Use the two handles on the front of the Laser Tracker Measuring Head when removing it from the shipping container. Use the upper front and back handles when mounting and carrying the Laser Tracker Measuring Head.

Pinch Points

Two labels that indicate pinch points are located on both the frontsight and the backsight side of the Laser Tracker Measuring Head's center eye wheel. Avoid placing hands and fingers in these pinch points. See Figure 2-6 for the location of the pinch point labels.

Figure 2-6 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 2-7 for the location of the hot plugging caution label.

Figure 2-7 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 tracker 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 and Voice System sold by FARO Technologies, Inc., *do not* cause interference.

Chapter 3: The FARO Laser Tracker ION System

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

Laser Tracker Measuring Head

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

Figure 3-1 Laser Tracker Measuring Head

The Laser Tracker Measuring Head lights indicate the following:

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

- Solid - Locked on target, valid beam
- Blinking - Locked on target, invalid beam, not ready to measure

NOTE: Before the Laser Tracker Measuring Head is initialized the green aperture light may blink.

Base Yellow Lights

- Blinking - One of the Laser Tracker Measuring Head's axes has rotated to an end stop

Base Red Light

- Solid - Laser is On and stable
- Blinking - Laser is On and unstable
- Off - Laser is Off

Base Green Light

- Solid - Power On
- Off - Power Off

Base Blue Light

- Solid - All Electronic Systems working correctly
- Blinking - Thermal Stabilization running
- Off - An electronic problem has occurred. Contact FARO Customer Support.

Master Control Unit

The Master Control Unit (MCU) provides power and communication to the Laser Tracker Measuring Head. On the left side of the MCU, there is a socket for a cable that connects to the Laser Tracker Measuring Head. See Figure 3-2.

Figure 3-2 MCU left side

The front of the MCU has eight (8) connectors for external temperature sensors, which can monitor the temperature of the ambient air or measured part. The RJ45 connector located on the bottom right of the front panel is used for the FARO

TrackArm cable - this connection does not support communications with your computer. Additionally, the MCU has two round 2-pin jacks for transistor-transistor logic (TTL) triggering. The left jack is the input and right is the output. See Figure 3-3.

Figure 3-3 MCU front panel

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 3-4.

Figure 3-4 MCU right side

For more information on connecting the MCU to the computer, see *"Hardware Configuration" on page 116*.

The MCU lights indicate the following:

Symbol	Light Color	Function
	Green	Power
	Red	Laser Emission
	Green	Ethernet Receive
	Green	Ethernet Transmission
	Yellow	Ethernet Connection
	Yellow	Ethernet Collision

Optical Targets

You can use a number of target types with the ION. 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* (part #922-01933) or the *FARO Laser Tracker Accessories Manual* (part #922-02413) for cleaning details.

Spherically Mounted Retroreflector (SMR)

The Spherically Mounted Retroreflector (SMR) is the most commonly used target with the ION. 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 ±30°.

Figure 3-5 Spherically Mounted Retroreflector (SMR)

You can attach the SMR to a target adapter. The combination of the SMR and the adapter will have a different 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 102* or *“Probes” on page 117*.

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 3-6 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 better than 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 3-7 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 3-8 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. 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.

Software - CAM2

CAM2 Measure 10, CAM2 Q, and CAM2 Measure X are CAD-based measurement and analysis software programs developed for use with a variety of 3D measurement instruments, including the ION. Use CAM2 for simple go/no-go measurements or CAD-to-part comparison. CAM2 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 ION with CAM2 software, see individual chapters later in this manual:

"CAM2 Measure" on page 101.
"CAM2 Q" on page 109.
"CAM2 Measure X" on page 115.

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 100 feet away from the computer.

Refer the Quick Start Guide for the RF Remote, FARO Part Number XH08-0394, for setup and operation information.

Remote Input Trigger

The ION is capable of recording measurements at the command of a remote trigger connected to the MCU External Trigger Switch. This allows the Laser Tracker System to accept measurement commands from a controller of a robot, CNC, or other external device.

The trigger input to the MCU works by using a +5 Volt TTL signal. The standard way to do this when using isolated contacts is to have the contacts Normally Closed and supplying +5V to the trigger input. When the contacts are opened, the input is pulled down by an internal 50 Ohm resistor making this an active low trigger. When the MCU senses this change, a measurement is taken.

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

The cable from the machine controller to the MCU can be as long as is physically required for the application, provided that the voltage at the MCU is at least +3V. FARO recommends a shielded cable for use in electrically noisy environments. On the MCU's trigger port, connect the top pin to the +5V and connect the bottom pin to ground. FARO part number 288-01579 is a shielded 10' cable for connecting the MCU to the controlling device.

CAM2 software, Measure Pad from FARO Utilities, and the FARO Software Developer's Kit support the Remote Trigger.

Chapter 4: Key Components of the FARO Laser Tracker ION

Key components of the ION are the Weather Station, the two Angular Encoders, the Absolute Distance Measurement (ADM) system and the Interferometer (IFM) system.

Weather Station

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. For the interferometer, the wavelength of the laser light in the air is a function of the known wavelength in a vacuum and the prevailing environmental conditions. Because both the ADM and the interferometer depend on current environmental conditions to calculate the speed of light and convert the measured waves into a distance, the accuracy of the temperature, pressure sensors, and humidity sensors must be established.

Temperature Sensor

Calibration of the remote temperature sensor for the ION is preformed at the factory by comparing its readings to a NIST (National Institute of Standards and Technology) traceable precision standard temperature sensor. The Standard Calibration Certificate provided will all Laser Trackers includes this comparison data.

Pressure Sensor

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

Humidity Sensor

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

Angular Encoders

The angular encoders in the ION are mapped against a reference encoder during the manufacturing process. To produce the highest quality Laser Tracker, our quality procedures require that all reference encoders used for this part of the manufacturing process are certified to NIST or International standards.

Distance Measurement System

AgileADM

Calibration of the ADM frequency oscillator is preformed using the cesium clocks within the Global GPS Network. The ADM System is then factory compensated using an interferometer. To produce the highest quality Laser Tracker, our quality procedures require that all reference encoders used for this part of the manufacturing process are certified to NIST. The optional ASME (American Society of Mechanical Engineers) B89.4.19 System Calibration includes calibration of the ADM system by comparing its readings to a NIST traceable interferometer using a procedure in accordance with the ASME standard.

Interferometer

The Helium Neon (HeNe) laser source assembly is stabilized to a known wavelength using a reference HeNe laser tube during the manufacturing process. To produce the highest quality Laser Tracker, our quality procedures require that all reference laser tubes used for this part of the manufacturing process are certified to NIST.

Certificate of Calibration

All FARO Laser Trackers come with a Standard Calibration Certificate that provides NIST Certification of the Laser Trackers Temperature and Pressure sensors, and basic radial values. FARO's quality control process requires that several factory only compensations be performed followed by additional tests to verify Laser Trackers measures within the accuracy specifications. FARO recommends annual recertification of the Laser Tracker. *For more information, see “Product Specifications” on page 47.*

If required by your company's quality control system or if interested in the calibration values of the transverse or angular system, an additional calibration performed in accordance to the 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 ION system depend on characteristics of the Spherically Mounted Retroreflector (SMR) such as:

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

The specifications for the ION 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 ION. *See "Optical Target Care" on page 41.*

Chapter 5: Setting up the FARO Laser Tracker ION

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

Unpacking the System

The ION 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 container, grasp the handles located on the front of the Laser Tracker Measuring Head. Never grasp the rotating Azimuth and Zenith axes of the Laser Tracker Measuring Head as this can cause damage.

ION System Contents

The ION includes the following:

- Laser Tracker Measuring Head.
- Master Control Unit (MCU), 30-foot communication/power cable, and power (120 or 240 VAC) cable.
- Remote Air Temperature Sensor - With 30' cable and NIST traceable documentation (4pin with gray boot, single keyed connector).
- High Accuracy Level Sensor - Allows measurement of a plane perpendicular to gravity.
- Compensation Kit - equipment required for measurement and field compensation. Includes one tripod, and one tripod nest.
- Computer to MCU Ethernet cable - 8 meter CAT5 100MHz crossover patch cable with RJ45 connectors.
- Assembly Instructions - Laser Tracker Assembly Instructions, Optical Target Care, Folding Tripod Assembly Instructions (optional).
- User Manuals - The following documentation is provided: ION Users Manual, and FARO Laser Tracker Accessories Manual.
- Quick Release Mandrel Mount - Allows for quick mounting to an instrument stand.

- Dust Cover - A cover to protect the Laser Tracker Measuring Head when not in use. The cover is only necessary in very dirty environments.
- Cable Cover - 25-foot cover designed to protect the 30-foot cable. Bundle the 30-foot communication/power cable and remote temperature sensor inside the cover.
- Documents - NIST traceable certification documentation.
- Heavy Duty shipping cases - One case for the Laser Tracker Measuring Head and one case for the MCU and accessories.

Optional Equipment

Your ION 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 ION 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 30' cable.
- Target Tooling Kit - Tooling for the 1.5" SMR. Includes drift nests, pin nests, a shankless nest, edge finders, etc.
- Wireless Ethernet - Provides wireless connection between the PC and the MCU.
- Hot glue gun and glue sticks.

Mounting

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

1 Mount the Laser Tracker in the vertical position on an instrument stand or a trivet through the use of the expanding mandrel. Screw the expanding mandrel onto to the instrument stand using a 3.5”-8 UN-2B thread. Using the optional Side Mount (Part Number 099-01138) and the expanding mandrel, the Laser Tracker can be mounted in the horizontal position on an instrument stand.

2 The mandrel receptacle at the bottom of the Laser Tracker also has a bolt pattern that can also be used for mounting. This bolt pattern consists of eight (8) 0.25”-20 UNC-2B holes spaced equally apart at 45 degree intervals. The bolt pattern forms a circle diameter of 3.125”.

3 The receptacle at the bottom of the Laser Tracker is threaded into the bottom of the Laser Tracker. This receptacle can be removed from the Laser Tracker to expose the same 3.5”-8 UN-2B thread the expanding mandrel has. Removing the mandrel receptacle allows the Laser Tracker to be threaded directly onto an instrument stand.

CAUTION: The expanding 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 and that the quick release mandrel mount is screwed firmly onto the top of the stand using the supplied “C” spanner wrench.

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 (FARO part #13642) 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 Laser Tracker Measuring Head

The Laser Tracker Measuring Head easily mounts to the instrument stand:

1 lower the Laser Tracker Measuring Head onto the mandrel mount.

2 Lock the Laser Tracker Measuring Head in position by moving the locking lever clockwise (when viewed from above) by hand until it is tight.

3 Check the stability of the mount by trying to turn the base of the Laser Tracker Measuring Head.

NOTE: 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 ION 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 Connect the 30 foot communication/power cable to the socket on the back of the Laser Tracker Measuring Head and to the socket on the left side panel of the MCU.

3 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.

4 Connect the remote air temperature sensor to port 1 on the front of the MCU.

5 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 30 foot 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 or MCU. You can safely connect the Ethernet cable and the air temperature sensor when the system is turned on.

Power Requirements

The ION will operate between 88 - 264 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 ION 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 ION 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 ION ships with fuses and the fuse tray specific to the region. Fuse trays for the other region 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. For both style fuse trays, 250 V fuses. The size of the fuses is IEC 60127-2, 5 x 20 mm.

Powering Up

Apply power to the ION by pressing the switch on the right side of the MCU. Immediately after pressing the power switch, all five lights on the front of the Laser Tracker Measuring Head and the red and green lights next to the laser aperture blink while the system starts, which is usually complete in 45 seconds. When the Laser Tracker is ready, the two end stop lights on the Laser Tracker Measuring Head will stop blinking. The MCU's power light, laser emission light and Ready Light (Green check mark) will also be lit.

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 then 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 blue light on the front 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 ION 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 tracker 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 tracker to achieve a stable operating temperature but 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 front 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, the button to skip stabilization must be selected 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 tracker 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 tracker 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 tracker 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.

Laser Stabilization

On Laser Trackers with the IFM system, after the Laser Tracker system successfully starts, the red laser indicator on the Laser Tracker Measuring Head continues to blink until the laser stabilizes, which takes 5 to 10 minutes. The ION special order ADM Only model does not require laser stabilization, so the red laser indicator will become solid red as soon as the Laser Tracker starts.

To maintain a stable laser frequency, the laser tube adapts to large changes in ambient temperature (up to ±15°C) by varying its internal temperature to maintain a constant tube length. During Laser Stabilization, the laser tube heats to a temperature higher than the current ambient temperature for a brief period of time, and then stabilizes to a set point, from which the ambient temperature can vary up to ±15°C.

If the ambient temperature changes considerably from when the IFM source was first energized, the laser may re-stabilize itself. The re-stabilization process it automatic and completes in less than five minutes.

Startup Checks

Each time the ION is powered up, or when power to the Laser Tracker 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 software when the ION is started as the current input device. *For more information, see "Device Setup" on page 115.*

1 Start the CAM2 software.

2 CAM2 automatically starts the Startup Checks.

Figure 5-1 Startup Checks

NOTE: The Thermal Stabilization may take up to 20 minutes to complete, depending on the initial tracker temperature. Thermal Stabilization can be skipped by clicking on the Thermal Stabilization 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.

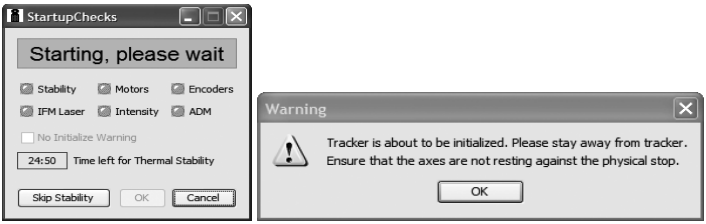


Figure 5-2 Startup Checks

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 63.*

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 66.*

NOTE: Upon completion of Angular Accuracy Checks, CompIT may recommend a Self Compensation to improve the Laser Trackers accuracy.

Self Compensation

Self Compensation is a routine that corrects for angular measurement error. It is a fully automated routine and is the fastest method of compensating the Laser Tracker System.

Click the SELF COMPENSATION button in the CompIT main menu to start the routine. When complete (approximately five minutes), the Laser Tracker System is within the pointing accuracy specifications and ready to measure. *For more information, see "Self Compensation" on page 70.*

NOTE: After the Self Compensation routine, Angular Accuracy Checks should be used to verify the accuracy. If an Angular Accuracy Checks was not performed immediately before the Self 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 Self 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 three parts of Pointing Compensation:

- An Interim Test (IT)
- Compensations
- Self-Comp Optimization

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 74.*

ADM Checks

The ADM (Absolute Distance Meter) Checks verifies the accuracy of the ADM radial measurement. The ION special order ADM Only model compares the ADM measurement to the angular measurement of the Laser Tracker Measuring Head. With the IFM, the system compares the ADM measurement to the Interferometer (IFM) measurement. *For more information, see "ADM Checks" on page 83.*

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 front 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 left side panel of the MCU.

8 Unlock the locking lever by moving the locking lever counterclockwise (when viewed from above) until it is loose, and carefully remove the Laser Tracker Measuring Head from the stand by grasping the upper handles.

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 airs index of refraction is critical for the accuracy of the radial distance measurements performed by the Laser Tracker's ADM system or its IFM 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 travelling 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 102.*
- CAM2 Q - *See "Probes" on page 110.*
- CAM2 Measure X - *See "Probes" on page 117.*

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 66.* These checks compare a point reading taken in frontsight mode with one taken in backsight mode. The resulting deviation reports twice the worst-case error for a point measured at the range and position of the backsight 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 then 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 ION to perform within the published specifications, either Thermal Stabilization needs to be allowed to complete or the tracker should be powered on, locked onto a 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 using the Angular Accuracy Checks (AAC) and run Self Compensation or Pointing Compensation if necessary.
- When measuring quickly after setup is more important than having the best accuracy, running an AAC every 15 minutes and performing a Self

Compensation or Pointing Compensation is the best method to manage the warm-up cycle while measuring.

- Self 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 tracker and running a Pointing Compensation is required.
- Periodically check for movement between the part and the Laser Tracker 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, even when using ADM Only. 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 travelled around the curve. Use the HARDWARE CONFIGURATION command in the measurement software to change this setting.
- 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 ION

Use care in handling the ION 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 ION. 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 ION 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 shipping cases. Always use straps to secure the shipping cases to a pallet when using a forklift, and gently lift and lower the pallet.

Chapter 8: Getting Help

This chapter describes the different resource tools that you should use to get help with your ION 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 ION and contains a help file that covers an extensive range of topics.

Documentation

This User Manual covers topics associated with the use of the ION 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 55 and "FARO CompIT" on page 63.

Other FARO Publications include the user manual for FARO's CAM2 Measure inspection software which covers the use of the software, and the FARO RetroProbe User's Guide which covers the use of the FARO RetroProbe 100/400.

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
Phone, Fax or E-Mail. *See "Technical Support" on page 129.*

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

International Mailing Addresses

FARO Europe GmbH & Co. KG
Lingwiesenstrasse 11/2
D-70825 Korntal-Münchingen
Germany

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

FARO Japan
716 Kumada, Nagakute-Cho,
Aichi-Gun, Aichi-Ken
480-1144 JAPAN

FARO Singapore Pte. Ltd.
3 Changi South Street 2
#01-01 Xilin Districentre Building B
SINGAPORE 486548

Chapter 9: Product Specifications

This chapter contains the ION 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	311(W) x 556(H) mm
Master Control Unit	282(L) x 158(D) x 214(H) mm

WEIGHT

Laser Tracker Measuring Head	17.7 kg
Laser Tracker Measuring Head with IFM	19.5 kg

RATED CONDITIONS

Measurement Envelope	
Distance	55 m with select targets 40 m Standard 1.5" & 7/8” SMRs 30 m Standard 1/2” SMR
Range of horizontal angle	360 degrees
Range of vertical angle	125 degrees
a. *Temperature Range*	
Operating	Min -15°C, Max 50°C
Thermal Gradient Limits	Max any °C/m Max any °C/hr
b. *Humidity*	
Operating	Min 0% RH, Max 95% RH
c. *Barometric Pressure Range*	
Operating	Min 562 mmHG, Max 825 mmHG

d. *Ambient Light*	Direct exposure to sunlight or flash lamps may compromise performance.
e. *Electrical*	
Voltage	88 - 264 VAC ± 10%
Current	5A (US), 2.5A (EU)
Frequency	50/60 Hz
Surge	1000 V common, 500 V differential, 1.25/50µs 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
f. *Probe Type*	
Diameter	1.5 in., 0.875 in., or 0.5 in.
Reflector Type	Spherically Mounted Retroreflector (SMR)
g. *Sampling Strategy*	
Acquisition time	1 sec
Frequency	1000 points/sec

LIMITING CONDITIONS

h. *Temperature Range*	Min -20°C, Max 70°C
i. *Humidity Range*	Min 0% RH, Max 100% RH
j. *Barometric Pressure Range*	Min 453 mmHG, Max 1500 mmHG

* Any temperature gradient can be accommodated if (1) appropriate formulas are used to compensate for air refraction effects and (2) an interim test is periodically performed and an angular compensation (pointing compensation or self compensation) carried out as required.

Spherically Mounted Retroreflector (SMR)

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

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

The specifications for the ION 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 ION. *See "Optical Target Care" on page 41.*

Measurement Specifications

Angular Encoders (transverse)

Horizontal Envelope ±270°

Vertical Envelope 125° (+72.5° to -52.5°)

Maximum Angular Measurement Velocity 180°/sec.

ADM (radial)

Sample Rate 10,000 samples/second

Resolution 0.5 µm

Working Range

Minimum Working Range 0 m

Maximum Working Range:
55 m with select targets
40 m Standard 1.5" & 7/8" SMRs
30 m Standard 1/2" SMR

Laser Interferometer

Maximum Radial Velocity 4 m/sec.

Resolution 0.158 µm

Level

Accuracy +/- 2 arc seconds

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 ION 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 ION. 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	
Interferometer (IFM)	e_{IFM}	$4\mu m + L \cdot 0.8\mu m/m$	(1)
Absolute distance meter (ADM)	e_{ADM}	$16\mu m + L \cdot 0.8\mu m/m$	(2)
R0 parameter (R0)	e_{R0}	$16\mu m$	(3)
Transverse	e_r	$20\mu m + L \cdot 5\mu m/m$	(4)

Table 9-1

Measurement Type	Symbol	Error	
Radial (IFM or ADM)	E_{TEMPR}	$L \cdot (\Delta T_{AVE}/°C) \cdot (1\mu m/m)$	(5)
Transverse	E_{TEMPT}	$0.5 \cdot (L^2 \partial T/\partial x)_{EFF} \cdot (1/°C) \cdot (1\mu m/m)$	(6)

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.

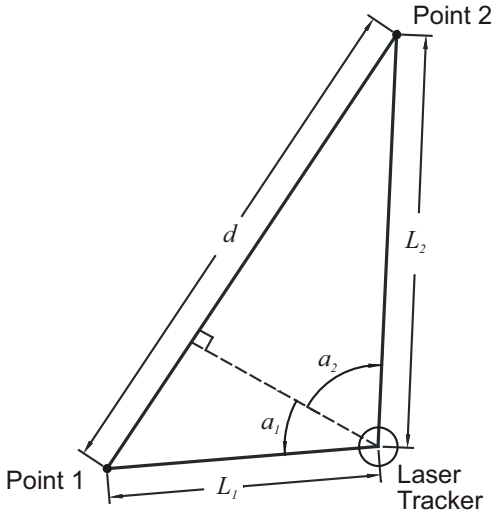


Figure 9-1 Laser Tracker Measuring Head *Geometry*

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

Figure 9-2

The angles a1 and a2 are positive in the directions shown in Figure 1 and negative in the opposite directions. The quantities eR1, eR2, eR0, eT1, and eT2 are calculated using Equations (1) - (4). 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 (5) and (6). The quantity ΔT_{AVE} in Equation (5) 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 (6) 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, $E_{TEMPT1} = 0.5 \cdot L_1^2 (\partial T/\partial x)_{EFF1} \cdot (1/°C) \cdot (1\mu m/m)$. In ordinary factory environments, the last four terms in Equation (7) - the thermal terms - can be ignored. In the testing of Laser Trackers at the FARO factories and service centers, these thermal terms in Equation (7) 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 9-2.

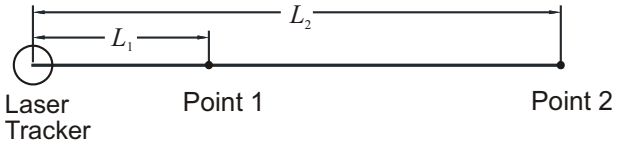


Figure 9-3 Laser Tracker Measuring Head *Buck-In Geometry*

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 (7) to be rewritten as:

$$MPE_d = e_{R12} + E_{TEMPR12} \qquad (8)$$

Here, the quantity e_{R12} refers to either the ADM or IFM 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 $E_{TEMPR12} = (L_2 - L_1) \cdot (\Delta T_{AVE12}/°C) \cdot (1\mu m/m)$, 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 frontsight 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:

$$MPE_{two-face} = 2e_{R1} \qquad (9)$$

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.

Nominal B89.4.19 MPE Values for 2.3 Meter Scale Bar

Scale Bar Measurements	MPE (IFM, micrometers)	MPE (ADM, micrometers)
Horizontal (0.2 m)	33	40
Horizontal (2.8 m)	47	48
Horizontal (6.2 m)	72	72
Vertical (2.8 m)	47	48
Vertical (6.2 m)	72	72
Right-Diagonal (2.8 m)	47	48
Right-Diagonal (6.2 m)	72	72
Left-Diagonal (2.8 m)	47	48
Left-Diagonal (6.2 m)	72	72
Two-Face (1.2 m)*	52,42,44	52,42,44
Two-Face (2.8 m)*	70,68,70	70,68,70
Two-Face (6.2 m)*	103,102,103	103,102,103

* For high, medium and low points

Table 9-3

Outside Buck-In Measurements	MPE (IFM, micrometers)	MPE (ADM, micrometers)
Ranging Test (6 m)	9	21
Ranging Test (12.5 m)	14	26
Ranging Test (19 m)	19	31
Ranging Test (25 m)	24	36

Table 9-4

Chapter 10: Operational Checks

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

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

ION Quick Start Guide (Part Number 922-03849)

Chapter 11: FARO CompIT. *See "FARO CompIT" on page 63.*

Equipment

1 ION 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. If you move the system to a new operating environment, 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 ION" on page 23.*

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 software.

Procedure

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

- CAM2 Measure 10 - On the DEVICE 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.
- CAM2 Q - Select DEVICE < DEVICE CONTROL PANEL 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.
- CAM2 Measure X - Select DEVICES < LASER TRACKER < OPERATIONAL CHECK (Alt S, L, O).

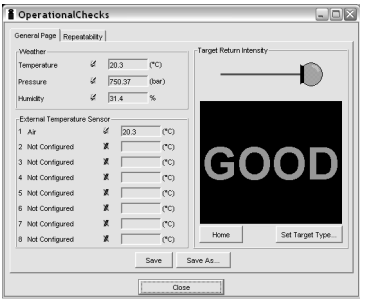


Figure 10-1 Operational Checks dialog box

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.

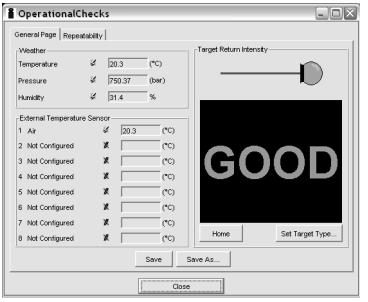


Figure 10-2 General Page of the Operational Checks

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.

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 41.*

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

2 Place the SMR at the Home position on the Laser Tracker Measuring Head and click the HOME button.

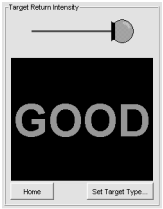


Figure 10-4 Target Return Intensity

Repeatability

The repeatability of measurements taken with the ION 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 tracker is consistent in its measurements in the current environment. It also contains a test for the IFM system to verify that it is measuring the radial distance consistently.

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

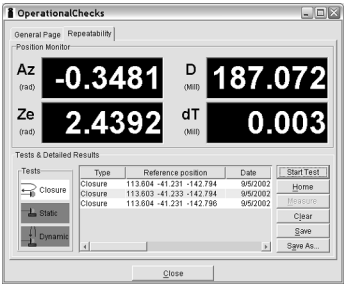


Figure 10-5 Repeatability

- 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.

Closure (For Interferometer Equipped Laser Trackers Only)

The Closure check applies to trackers with the optional IFM system. If you measure in IFM Only or IFM Set by ADM mode, FARO recommends you perform this check. If you will measure in ADM Only Mode, or if your Laser Tracker does not have the IFM option, you can skip this check. The Closure

check verifies that the interferometer is counting properly. A poor result on the test may also indicate a bad SMR or debris in the TMR.

NOTE: Even though this test is for the optional IFM system, it will be performed in the Laser Trackers current distance measurement mode. Prior to running this test, you should verify that the Laser Tracker mode is set to IFM or IFM Set by ADM.

1 Place the SMR in the TMR.

2 From the REPEATABILITY tab of the Operational Checks dialog box, click the HOME button to reset the laser.

3 Select the 

button and click START TEST.

4 Remove the SMR from the TMR and move it around the measurement volume, making sure that the SMR is constantly being tracked. If the beam is broken while tracking, you must return the SMR back to the TMR and restart the test.

NOTE: Make sure to move the SMR throughout the entire measurement volume, and to include the furthest point, or farther, in the measurement volume.

5 Return the SMR to the TMR and click MEASURE to record the repeatability.

NOTE: The Total value in the Test Results section should be in the following range: -0.005mm < Total < +0.005mm.

6 Repeat this procedure two (2) more times making sure to maintain the above criteria. Click STOP TEST to finish.

7 If the criteria in Step (5) is not met, clean out any dirt or debris from the TMR and use a different SMR if available, and then re-home the Laser Tracker System and repeat Steps (3) through (5) above. If the Closure Test still fails, contact FARO Customer Service for further instructions.

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 TMR.

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.

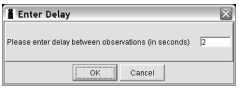


Figure 10-6 Enter Delay

- 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 TMR.

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 system 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 

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 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 Angular Accuracy Checks and Self Compensation prior to any measurement session to verify the accuracy of the system. *See "Angular Accuracy Checks" on page 66, and "Self Compensation" on page 70.*

Chapter 11: FARO CompIT

This chapter is a reference guide for FARO CompIT. Before continuing, you must have a working knowledge of the ION System and FARO CAM2.

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. After completing all tests and compensations, CompIT will compare the results to the Maximum Permissible Error (MPE) of the Laser Tracker per the ASME B89.4.19 Standard as defined in Chapter 9: Product Specifications. *For more information, see "Product Specifications" on page 47.*

Getting Started

Prior to running any test or compensations in FARO CompIT, set up, power up and start the FARO Laser Tracker. *See "Setting up the FARO Laser Tracker ION" on page 23.*

After the tracker is properly set up, you can start FARO CompIT from the CAM2 software menus or from the Windows Start Menu.

CAM2 Measure 10

In CAM2 Measure 10, 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.

CAM2 Q


In CAM2 Q select DEVICE < DEVICE CONTROL PANEL to show the DEVICE CONTROL panel. You can also press the P hot key to show the DEVICE CONTROL panel.

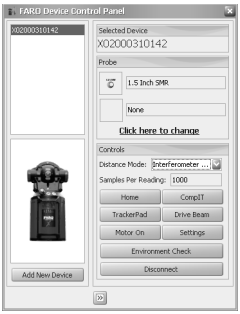


Figure 11-2 Device Control Panel

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

CAM2 Measure X


In CAM2 Measure X, choose DEVICES < HARDWARE CONFIG to show the HARDWARE CONFIGURATION dialog box.

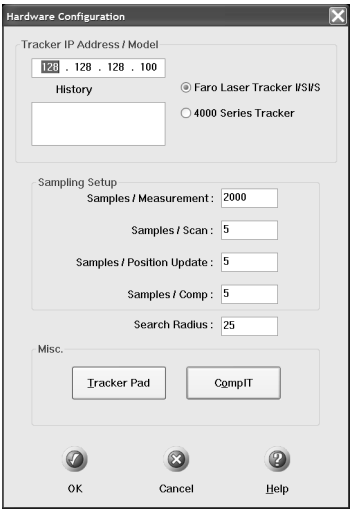


Figure 11-3 Hardware Configuration dialog box

- 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 Utilities program and clicking CompIT.

Figure 11-4 FARO Utilities dialog box

Standard Tab

Clicking the CompIT button displays the CompIT dialog box.

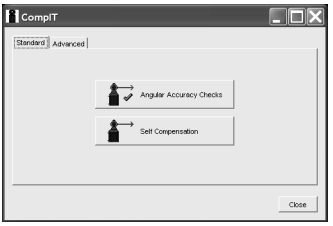


Figure 11-5 FARO CompIT dialog box

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

Angular Accuracy Checks starts the Angular Accuracy test. *See "Angular Accuracy Checks" on page 66.*

Self Compensation starts the Self Compensation routine. *See "Self Compensation" on page 70.*

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 frontsight 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 trackers Maximum Permissible Error (MPE) based on your Lasers Trackers specifications per the ASME B89.4.19 Standard. If the measured error is greater than the MPE, CompIT recommends a Self 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:

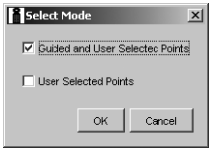


Figure 11-6 Select Mode dialog box

- 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 which Mode, the measurement screen appears:

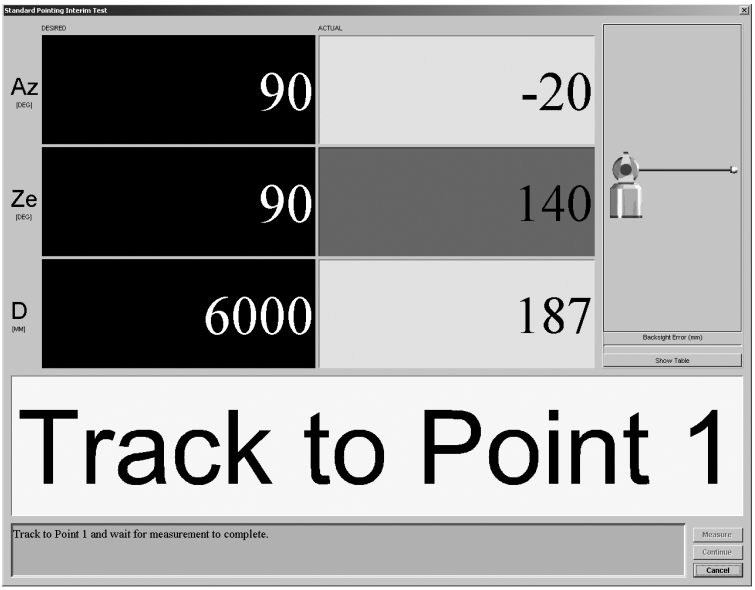


Figure 11-7 Guided and User Selected Points - Track to Point 1

- **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.

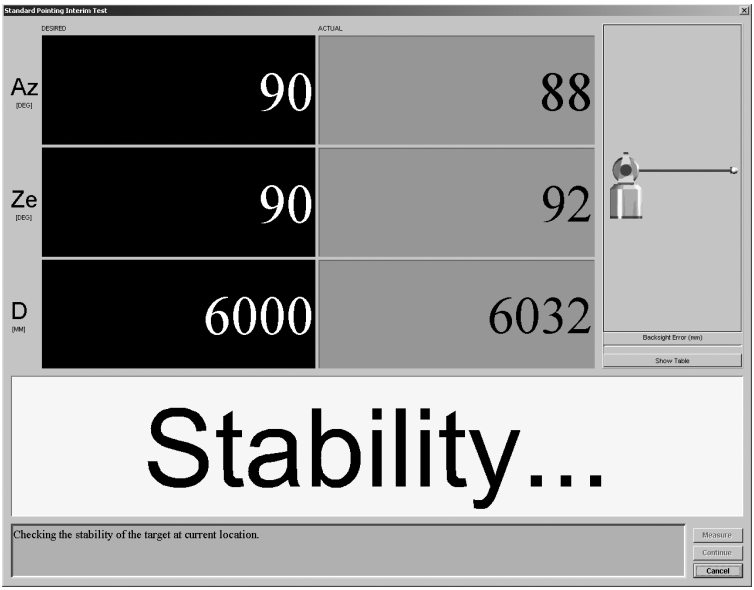


Figure 11-8 Stability

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.

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 98.* 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 97.* When Auto Measure is disabled, take measurements by clicking the Measure button.

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

4 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.

CompIT compares the measured Angular Accuracy to the trackers Maximum Permissible Error (MPE) based on your Lasers Trackers specifications per the ASME B89.4.19 Standard. The Results Dialog box will report PASS if the tracker results are in tolerance and will report CONTINUE with a recommendation to run the Self Compensation Routine if they are out of tolerance.

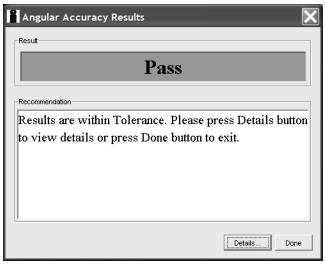


Figure 11-9 Angular Accuracy Results dialog box

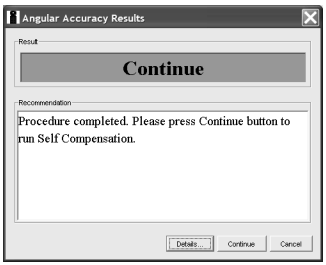


Figure 11-10 Angular Accuracy Check complete

5 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.

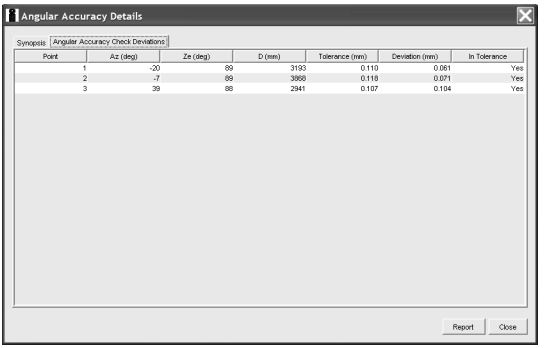


Figure 11-11 Angular Accuracy Check Deviations tab

6 Click CLOSE to continue.

Self Compensation

Self 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 trackers specifications for the full range of the system, or lower than the trackers Maximum Permissible Error (MPE) based on your Lasers Trackers specifications per the ASME B89.4.19 Standard.

Self Compensation is not necessary, if the Angular Accuracy Checks have recently been performed with passing results. Self Compensation can also be performed prior to performing the Angular Accuracy Checks using the steps below. When running the Self Compensation prior to performing the Angular Accuracy Checks, FARO recommends that you verify the Self Compensation results with an Angular Accuracy Check.

NOTE: Self Compensation is the fastest compensation for most applications but will not provide the best possible accuracy that the system is capable of measuring. Pointing Compensation from the Advanced tab of CompIT will produce lower backsight error or improved Angular Accuracy results, especially at longer distances. Therefore, for some measurement applications, especially when the best possible accuracy is desired or when measuring at long distances, Pointing Compensation will produce an improvement in overall measurement accuracy when compared to Self Compensation.

Equipment

Self Compensation uses the targets embedded on the tracker. It does not require an SMR or nests for measurements.

Procedure

1 In the CompIT dialog box, click the Self Compensation button. This step is not necessary if you chose to continue onto the Self Compensation directly from the results of the Angular Accuracy Checks.

2 CompIT begins the Self Compensation routine. This routine does not require tracking the SMR to any locations, it is automatic. The routine takes approximately five minutes to complete.

3 After the routine is completed, you will see the results in the SELF COMPENSATION RESULTS dialog box with a recommendation.

- If Self Compensation was run directly from the CompIT dialog box, a recommendation to press Update will be given (shown below).
- If Self 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 Self Compensation has improved the tracker's angular accuracy and it is now within its specifications. If these new results are not within the trackers accuracy specifications, CompIT will recommend that you press CONTINUE to perform a Pointing Interim Test and Pointing Compensation. *See "Pointing Compensation" on page 74.*

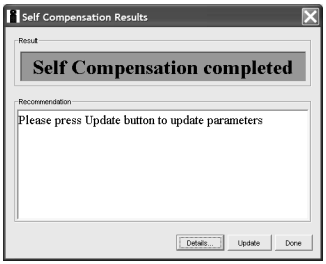


Figure 11-12 Self Compensation results

- Click UPDATE to save the results to the system If Self Compensation was run without performing the Angular Accuracy Checks immediately before or directly from the CompIT dialog box, before, CompIT will ask if you would like to run the Angular Accuracy Checks after Updating the parameters. FARO recommends that you run them to verify the accuracy of the Laser Tracker. Click YES to run the Angular Accuracy Checks, or NO to exit. *See*

“Angular Accuracy Checks” on page 66.

- Click DONE to exit the Self Compensation routine without making any updates.
- Click DETAILS to see detailed results.

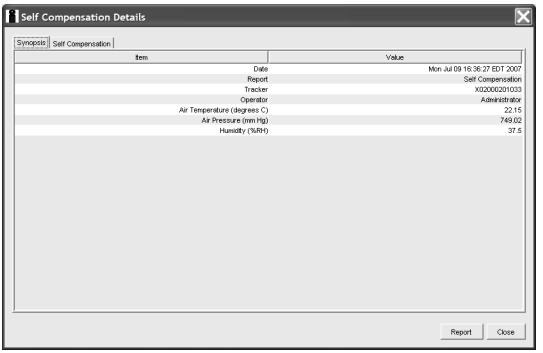


Figure 11-13 Synopsis tab

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

If Self 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 SELF COMPENSATION tab to view the Before, After and Change in system parameters. Self Compensation only 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 tracker. The Angular Accuracy Checks or Backsight results is used to evaluate the accuracy of the tracker, not these parameters.

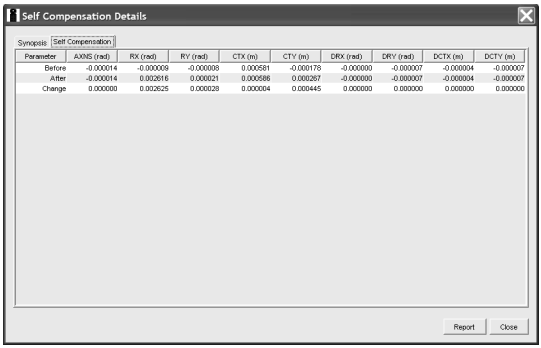


Figure 11-14 Self Compensation tab

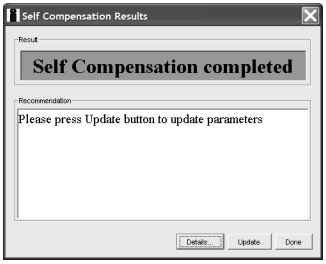


Figure 11-15 Self Compensation routine complete

Advanced Tab

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

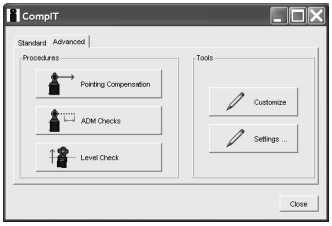


Figure 11-16 FARO CompIT dialog box - Advanced tab

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

Pointing Compensation starts the Pointing Compensation routine. *See "Pointing Compensation" on page 74.*

ADM Checks starts the ADM Interim Test. *See "ADM Checks" on page 83.*

Level Check starts the Level Check routine. *See "Level Check" on page 95.*

Settings changes Auto Measure function. *See "Customize" on page 97.*

Customize changes the CompIT default settings. *See "Customize" on page 97.*

Pointing Compensation

The Pointing Compensation, similar to the Self 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 trackers specifications for the full range of the system, or lower than the trackers Maximum Permissible Error (MPE) based on your Laser Trackers Specifications per the ASME B89.4.19 Standard.

Compared to the Self Compensation, the Pointing Compensation requires additional space and time to perform. Compared to the Self Compensation, the Pointing Compensation will yield lower backsight error or improved Angular Accuracy results in general and, especially at longer distances. Therefore, for measurement applications where the best possible tracker accuracy is the goal and when measuring at long distances, Pointing Compensation will produce an improvement in overall measurement accuracy as compared to running a Self Compensation.

The Pointing Compensation should also be performed if the Self Compensation does not adequately improve Angular Accuracy. In this case, the Pointing Compensation should be performed followed by the Axis Non-Squareness then followed by the Self Compensation Optimization.

The Pointing Compensation consists of four 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 tracker. The purpose of these points is to improve the Angular Accuracy as the radial distance from the tracker 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 trackers Zenith axis changes.
- Self Compensation Optimization: A procedure to improve the performance of the Self Compensation routine. *See "Self Compensation" on page 70.*

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: Allow the Laser Tracker Measuring Head thermally stabilize in the working environment before running a Pointing Compensation.

Interim Test

1 In the CompIT dialog box, click the Advanced tab and then click the Pointing Compensation button.

2 Follow the prompts and move the SMR to the Home position, and then to various default positions as indicated. Rotate the Laser Tracker Measuring Head on the mandrel mount to adjust the Azimuth angle to the target.

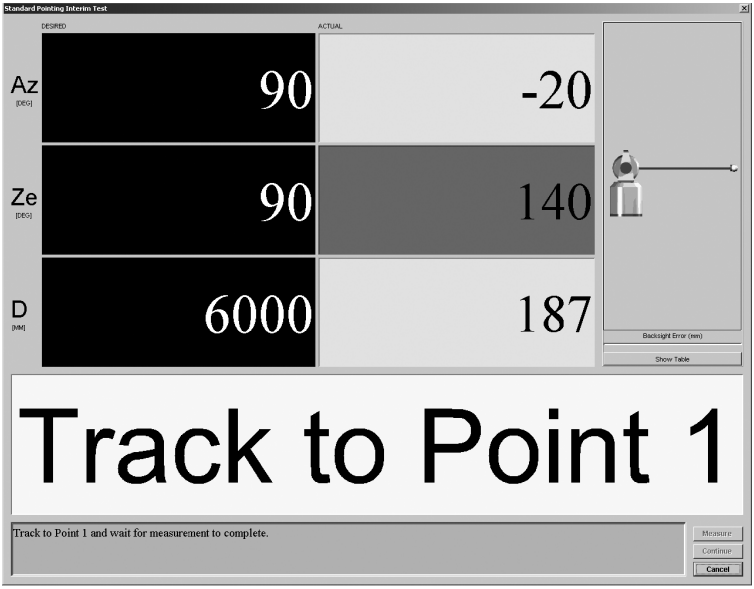


Figure 11-17 Track to Point 1

- **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 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.

3 Place the SMR in the calibration tripod or in another stable nest. The first desired location is:

- 90 degrees azimuth, 90 degrees zenith, 6 meters distance.

4 Move the SMR and/or rotate the Laser Tracker Measuring Head until the actual numbers for all three values are green.

Once the SMR is in the correct location, it is automatically checked for stability, and when stable is measured in both frontsight and backsight modes. The calculated difference between the two measurements is the Backsight Error.

The remaining desired locations are:

- -45 degrees azimuth, 90 degrees zenith, 2 meters distance.
- 45 degrees azimuth, 135 degrees zenith, 2 meters distance.

5 Move the SMR and/or rotate the Laser Tracker Measuring Head until the actual numbers for all three values are green for the second location. Repeat for the third.

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.

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

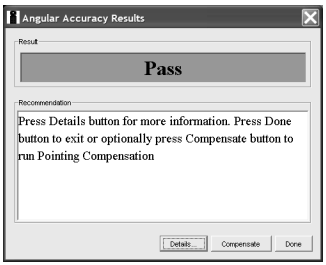


Figure 11-18 Angular Accuracy Results dialog box

7 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 and CompIT will report a result of PASS. Click DONE to exit CompIT. You can optionally click COMPENSATE to continue on with the Pointing Compensation to further improve the Angular Accuracy. If you are intending to perform a Self Compensation Optimization to improve the results from a Self Compensation, click COMPENSATE.

- If one or more points are out of tolerance or greater than the Maximum Permissible Error, CompIT recommends continuing onto the Pointing Compensation. Click COMPENSATE to continue.
- The DETAILS to view detailed results. The REPORT button on the Details page can be used 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.

1 Place the SMR in the calibration tripod or in another stable nest. The first desired location is:

- any azimuth position, 90 degrees zenith, 2 meters distance.

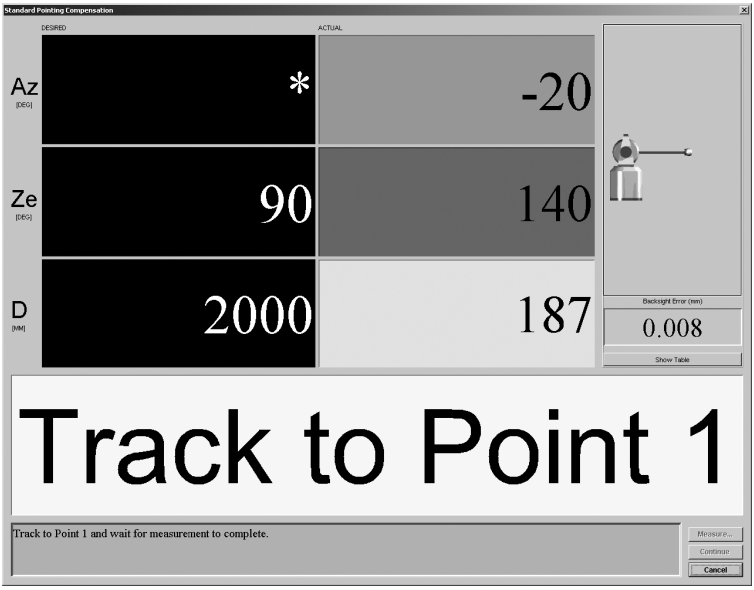


Figure 11-19 Track to Point 1

- **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 yellow 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.

- **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 Pointing Compensation without saving any data or parameters.

2 Move the SMR and/or rotate the Laser Tracker Measuring Head until the actual numbers for all three values are green.

Once the SMR is in the correct location, it is automatically checked for stability, and when stable is measured in both frontsight and backsight modes. The calculated difference between the two measurements is the Backsight Error.

The remaining desired locations are:

- 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 meters distance.

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

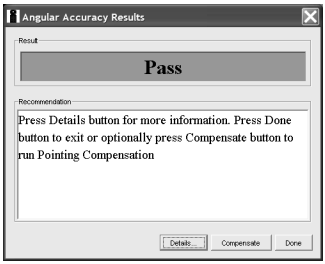


Figure 11-20 Pointing CompIT - Pointing Compensation Results dialog box

CompIT will calculate new parameters calculated 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 and CompIT will report a result of PASS. Click UPDATE to save the results and exit CompIT. You can optionally press COMPENSATE to continue on with the Axis Non-Squareness Compensation to further improve the Angular

Accuracy. If you are intending to perform a Self Compensation Optimization to improve the results from a Self Compensation, press COMPENSATE.

- 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 COMPENSATE to continue onto the Axis Non-Squareness Compensation.
- Click DETAILS to view detailed results. The REPORT button on the Details page can be used to save the results to a text file.

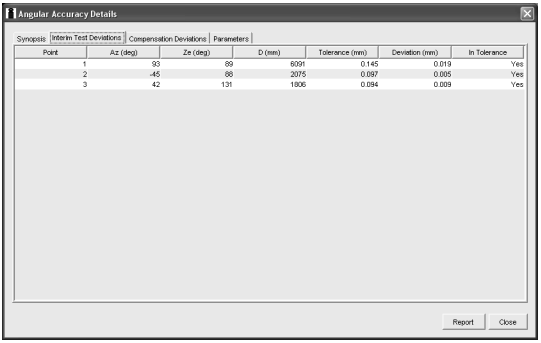


Figure 11-21 Pointing CompIT - Pointing Compensation Results dialog box - Interim Test Deviations

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.

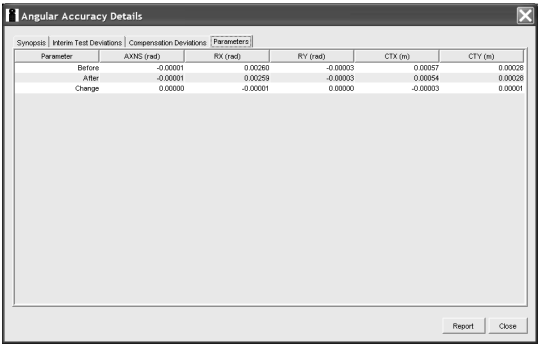


Figure 11-22 Pointing CompIT - Pointing Compensation Results dialog box - Parameters

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, 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

1 Follow the prompts and move the SMR to the Home position, then to various positions as indicated. The first desired location is:

- 0 degrees azimuth, 135 degrees zenith, 2 meters distance.

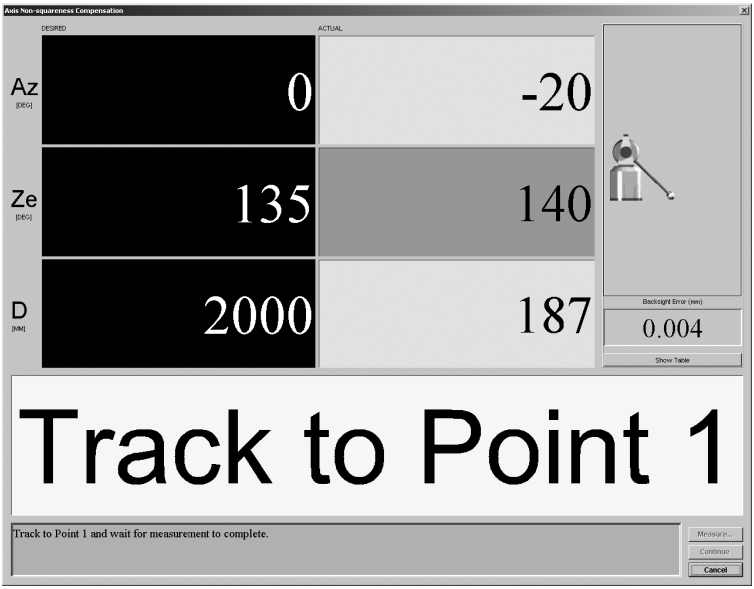


Figure 11-23 Axis Non-squareness - Track to Point 1

2 Move the SMR and/or rotate the Laser Tracker Measuring Head until the actual numbers for all three values are green.

Once the SMR is in the correct location, it is automatically checked for stability, and when stable is measured in both frontsight and backsight modes. The calculated difference between the two measurements is the Backsight Error.

The remaining desired locations are:

- 0 degrees azimuth position, 110 degrees zenith, 4.0 meters distance.

- 0 degrees azimuth position, 102 degrees zenith, 6.0 meters distance.

Figure 11-24 Axis Non-squareness - Angular Accuracy Results dialog box

- 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.
- Click COMPENSATE in the ANGULAR ACCURACY RESULTS dialog box to proceed with a Self Compensation Optimization., only if the Self Compensation routine is unable to sufficiently bring the backsight results into tolerance. *See "Self Compensation" on page 70.*

Self Compensation Optimization

1 CompIT begins the Self Compensation Optimization routine. This routine does not require tracking the SMR to any locations, it is automatic. The routine takes approximately five minutes to complete.

2 After completing the routine, you will see the results in the SELF COMPENSATION OPTIMIZATION RESULTS dialog box.

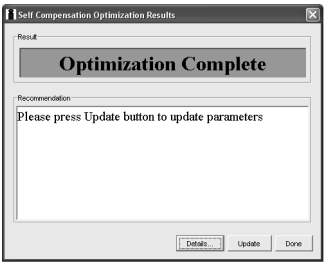


Figure 11-25 Self Compensation Optimization Results dialog box

- Click UPDATE to save the results to the Laser Tracker System.
- Click DONE to exit the Self Compensation Optimization routine.
- Click DETAILS to see detailed results.

ADM Checks

There are two different procedures, depending on your ION model. The ADM Only model ION procedure compares ADM (Absolute Distance Meter) measurements to angular measurements. The IFM procedure compares ADM measurements to Interferometer (IFM) measurements. The tests take only a few minutes and can be run weekly. *See "ADM Checks IT - ION ADM Only Model" on page 83 and "ADM Checks IT - IFM" on page 92.*

ADM Checks IT - ION ADM Only Model

On the model ION, the ADM Interim Test compares the distance between two points measured from a tracker 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 Laser Trackers 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 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 74.*

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. A percentage of 80% from this position can be obtained by placing 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

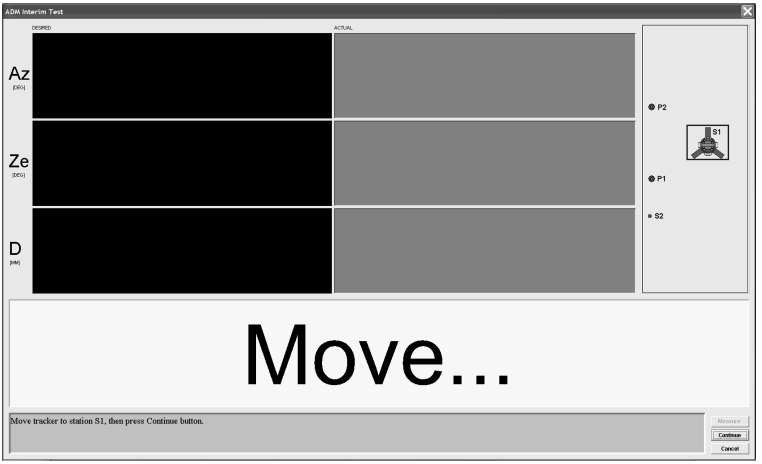


Figure 11-26 Move to Station S1

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.

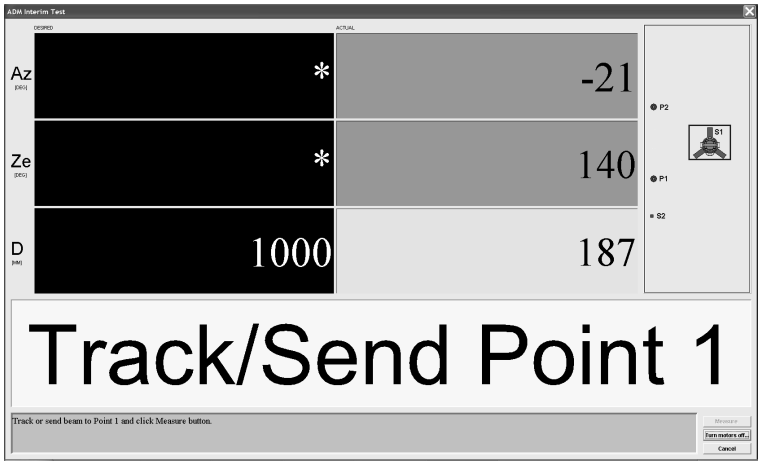


Figure 11-27 Beam to Point 1

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

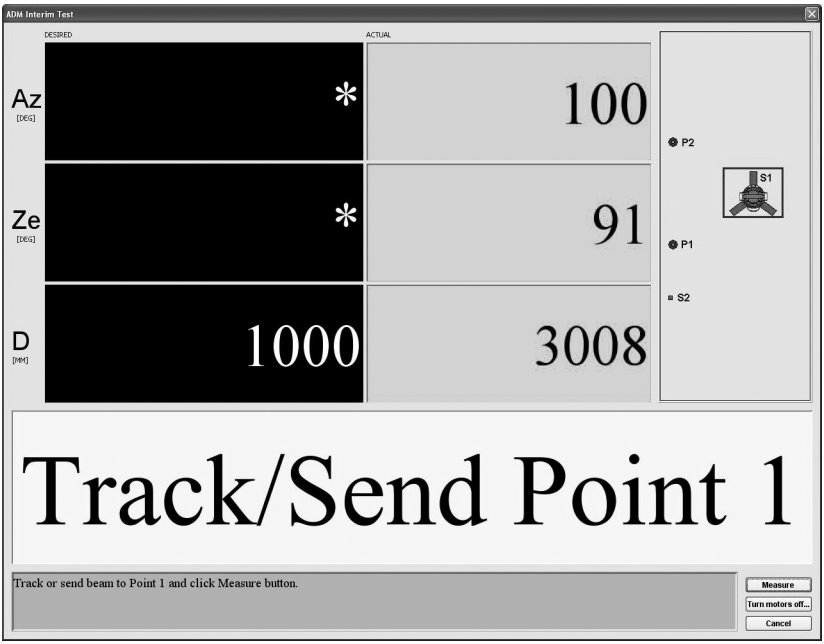


Figure 11-28 Measure Point 1

6 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.

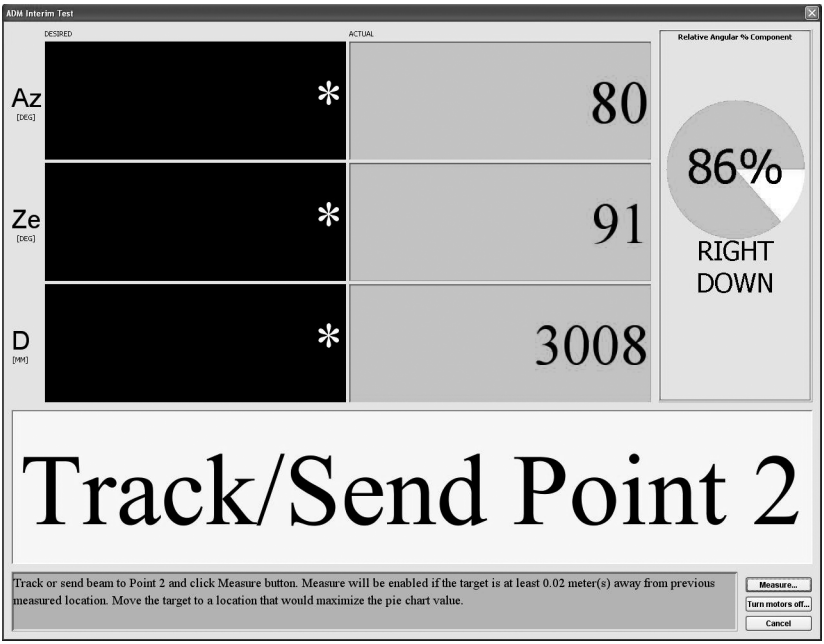


Figure 11-29 Beam to Point 2

7 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%.

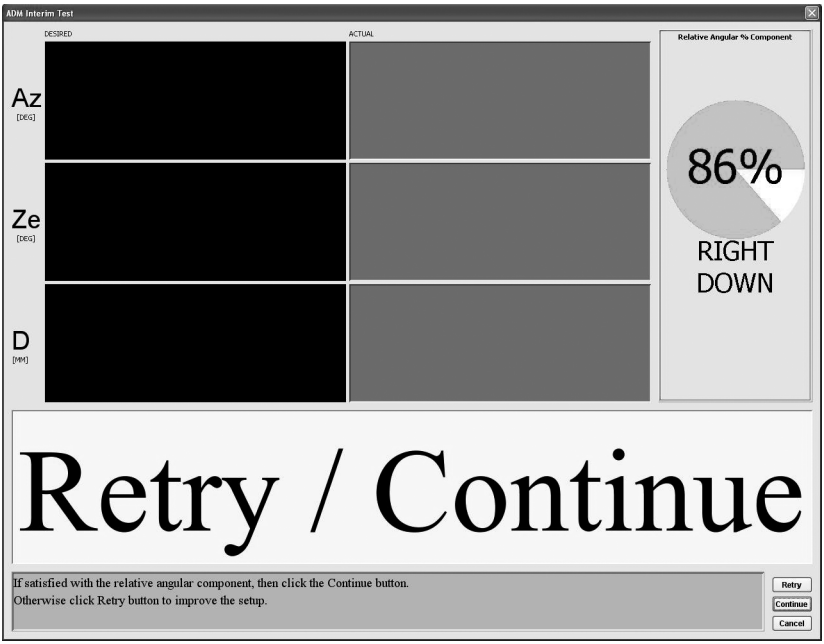


Figure 11-30 Retry/Continue 2

9 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.

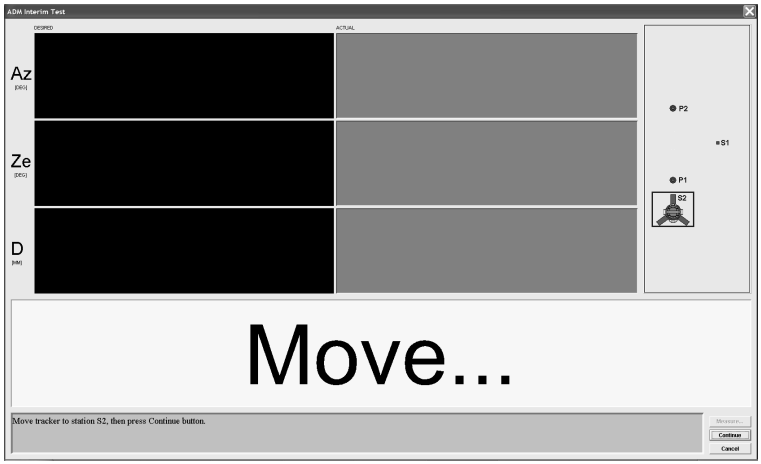


Figure 11-31 Move to Position 2

10Click MEASURE to measure Point 1. A check is made to ensure the target is stable before the measurement is taken.

11Track 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).

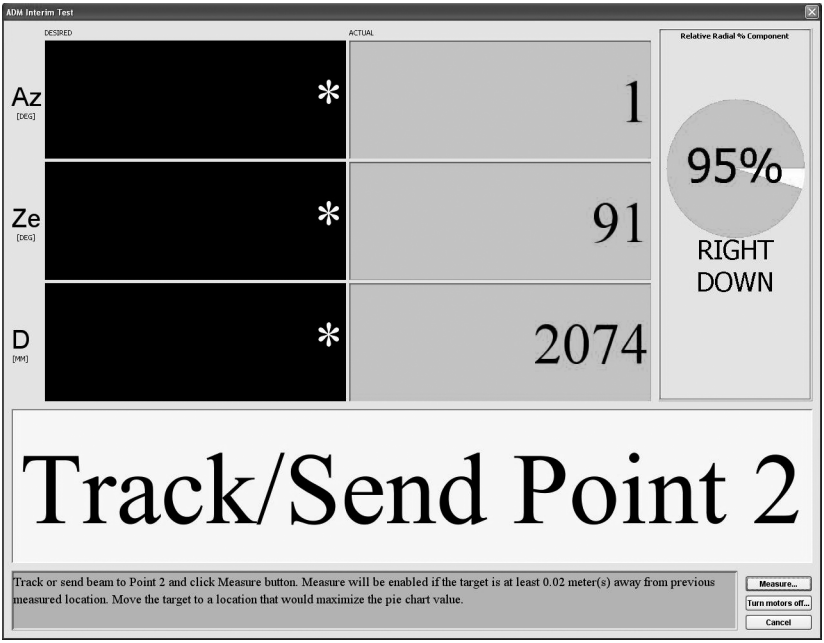


Figure 11-32 Beam to Point 2

12Click MEASURE to measure Point 2.

13If 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%.

14The 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.

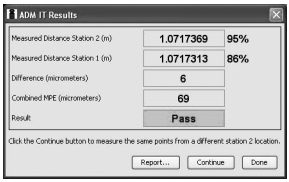


Figure 11-33 ADM IT Checks dialog box

15Clicking 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.

16The 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.

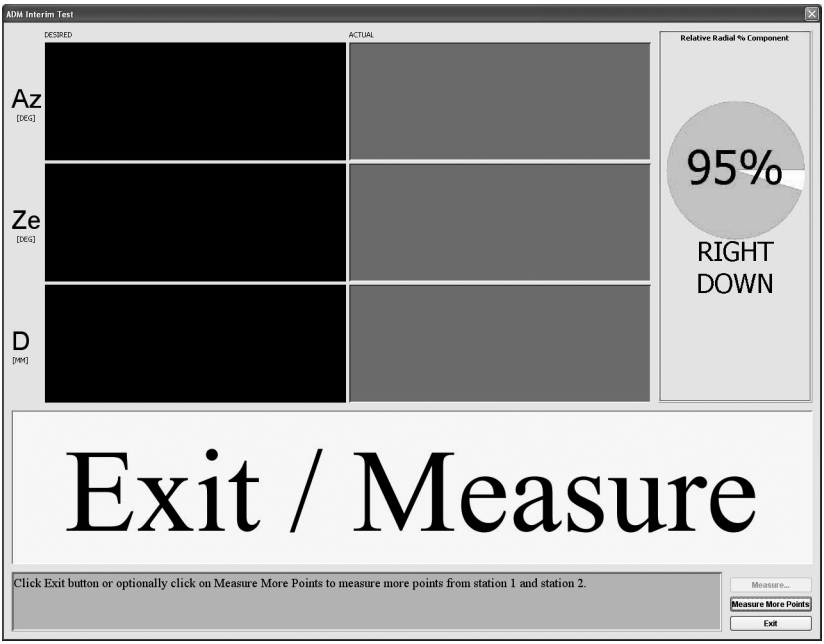


Figure 11-34 Measure More Points

17Click EXIT to end the test.

ADM Checks IT - IFM

On an ION with the Laser Interferometer (IFM), the ADM Interim Test compares the tracker ADM radial distance measurements directly to radial distance measurements taken with the trackers IFM.

Equipment

The ADM Interim Test will require a 1.5” Spherically Mounted Retroreflector (SMR) and a heavy duty nest that to place the SMR in that will remain stable during the time of the measurement.

Procedure

Always, use a stable nest for the SMR during this test, such as the Calibration Tripod or a heavy duty nest attached to a heavy object.

Throughout this test, Auto Home is active. If the beam is broken at any time, CompIT prompts you to return the SMR to the home position for an automatic reset.

1 In the CompIT dialog box, click the Advanced tab and then click the ADM Checks button. The SELECT MODE dialog box appears with two options:

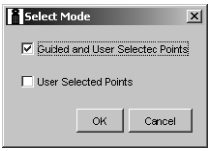


Figure 11-35 Select Mode dialog box

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

The laser beam moves to the Home position, and runs an Auto-adjust. The radial distance to Point 1 (Home) is measured with both the interferometer and the ADM.After selecting which Mode, the laser beam will move to the Home position to reset the distance for both the IFM and ADM system.

NOTE: If you selected GUIDED AND USER SELECTED POINTS, CompIT will then measure Point 1 at the home position.

2 After selecting which Mode, the measurement screen appears:

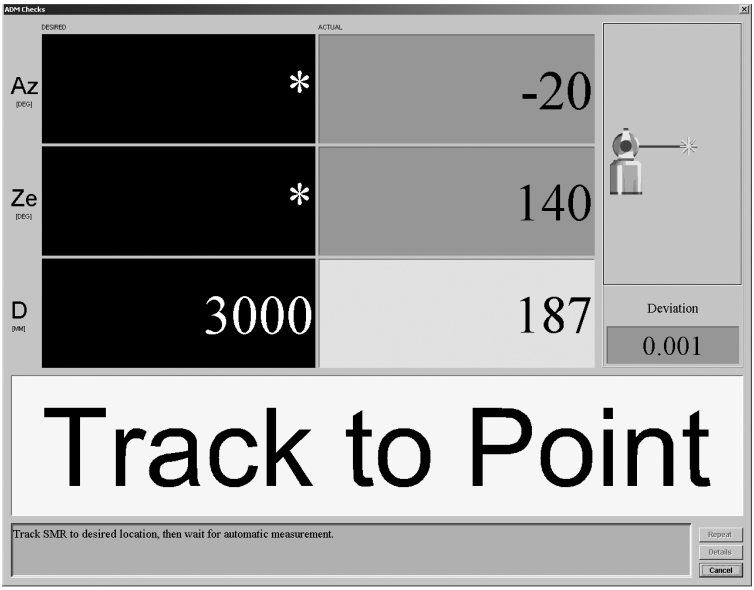


Figure 11-36 ADM Checks Test

- **DESIRED** value: When measuring Guided Points, this is the target value for the Radial Distance. When measuring User Selected Points, an * replaces the value instead of a specific distance. The Azimuth and Zenith Desired Values always show an * because any values can be used for the test.
- **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. The Azimuth and Zenith angle values will always be green. When measuring User Selected Points, the Radial Distance value will also always be green. When measuring Guided Points, the Radial Distance value will switch to green when the SMR is in an acceptable zone around the desired value. The Radial distance value switches to red if the SMR is beyond its desired value.
- **Deviation**: The ADM error of the last measurement. Click SHOW TABLE to show the ADM error for all previous measurements.
- **Cancel**: Exits the ADM Checks without saving any data or parameters.

NOTE: If any point is out of tolerance, CompIT prompts you to track Home to check for Closure. Return the SMR to the TMR position without breaking the beam. If Closure is not within acceptable limits, CompIT prompts you to repeat the measurement. If Closure is within acceptable limits, the ADM

Checks will report a Fail result. Perform the test again and contact FARO Customer Support for assistance.

3 When the measurements at the first location are complete, move the SMR to another location. Track the SMR to the next point and wait for stability.

4 After completing the last measurement, click DETAILS to see the results, or DONE to exit.

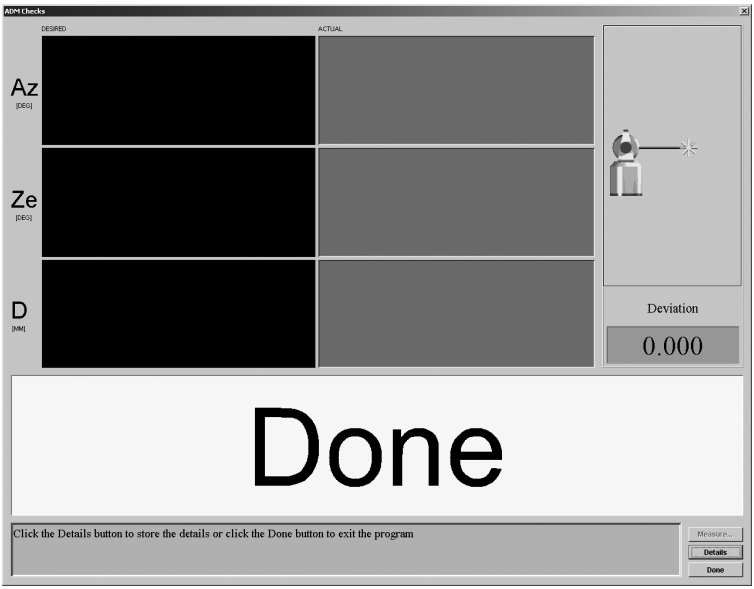


Figure 11-37 ADM Checks Results

Click DETAILS to see the results of this test in the ADM CHECKS RESULTS dialog box. Select the ADM INTERIM CHECKS tab to view the ADM-IFM values.

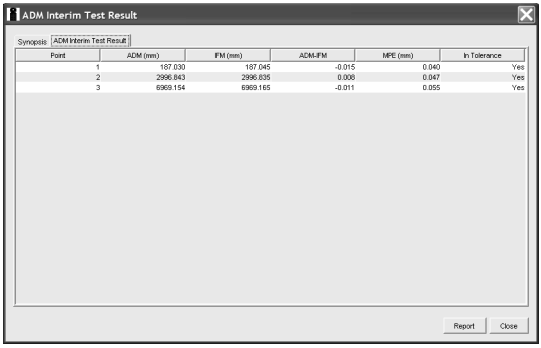


Figure 11-38 ADM Checks Results

- **ADM**: The radial distance to the SMR as measured by the ADM System.
- **IFM**: The radial distance to the SMR as measured by the IFM System.
- **ADM-IFM**: The results of the Interim Test.
- **MPE**: Maximum Permissible Error per the system's specifications and the ASME B89.4.19 - 2006 Standard.
- **IN TOLERANCE**: Yes if the measured error is below the MPE. No if the measured error is greater than the MPE.

5 Click CLOSE to exit the ADM Checks Results.

6 Click DONE to exit the ADM Checks procedure.

Level Check

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

Equipment

The Level Check requires the Laser Tracker to be setup on a stable stand in the upright position and leveled out using the trackers Electronic Bubble Level from the TrackerPad. *See "TrackerPad" on page 118.* 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's axis rotate around several times while performing the test.

2 Upon completion of the Level Checks, the LEVEL CHECK RESULTS appears:

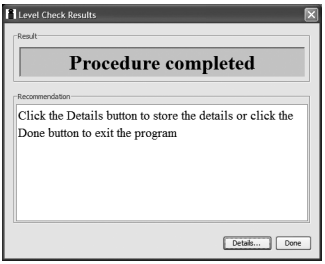


Figure 11-39 Level Check Results dialog box

Press DETAILS to see the detailed results:

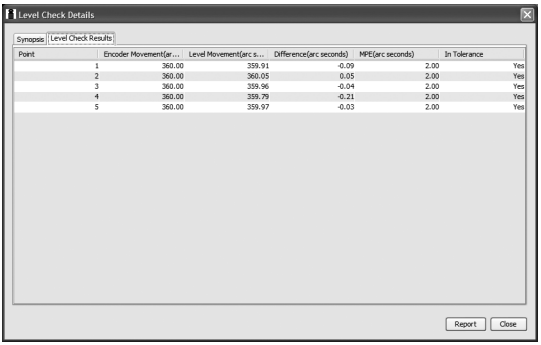


Figure 11-40 Level Check Details dialog box

- **ENCODER MOVEMENT** (arc seconds): The angular movement of the Laser Trackers axes measured by the its encoders.
- **LEVEL MOVEMENT** (arc seconds): The angular movement of the trackers 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 Click DONE to exit the Level Checks procedure.

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.

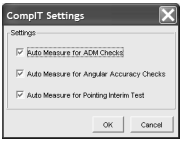


Figure 11-41 CompIT Settings dialog box

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.

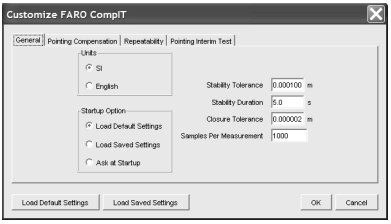


Figure 11-42 Customize dialog box

- 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.

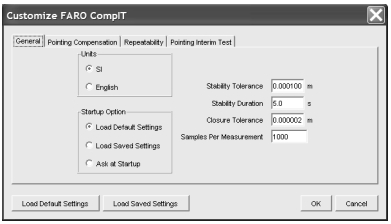


Figure 11-43 General tab

- Units - The unit of measurement for all of the routines when CompIT is started from the FARO 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.
- Closure Tolerance - The maximum interferometer closure error allowed when performing the ADM Checks on a tracker with the optional Interferometer.
- 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.

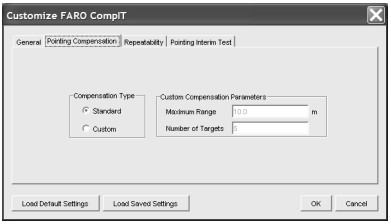


Figure 11-44 Pointing Compensation tab

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.

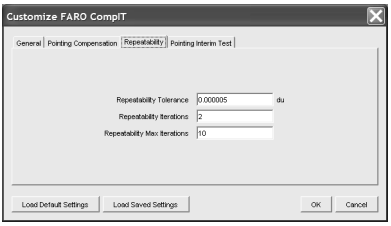


Figure 11-45 Repeatability tab

- **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.

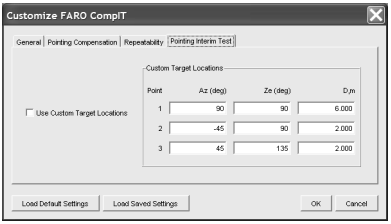


Figure 11-46 Pointing Interim Test tab

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

Chapter 12: Configuring the FARO Laser Tracker ION in CAM2 Measure 10

NOTE: This chapter describes the operation of your ION with CAM2 Measure v10, or later. For previous versions of CAM2 Measure, *see "Configuring the FARO Laser Tracker ION in CAM2 Measure" on page 115*.

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

You can also use the Laser Tracker 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 mor information about the SURVEY command, see the *Survey* section of the *Navigation Window* chapter in the CAM2 Measure manual.

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 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 FARO Laser Tracker's IP address and click CONNECT.

NOTE: The default IP address for a FARO Laser Tracker is 128.128.128.100.

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 ION 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 10 manual.

Probes

The Probes section of the DEVICE CONTROL panel shows the current SMR and Adapter for the current FARO Laser Tracker.

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.

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 FARO Laser Tracker.

Distance Mode: Choose a distance mode.

Samples Per Reading: Enter a value. The number of individual laser measurements of the SMR position for each reading in a measurement. 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 Home position.

CompIT

Click the CompIT button to start FARO CompIT. *For more information, see "FARO CompIT" on page 63.*

TrackerPad

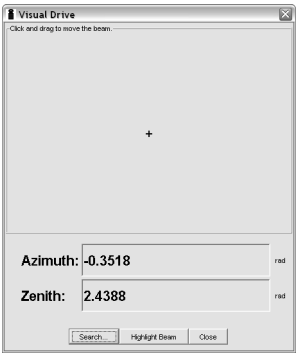
Click the TRACKERPAD button to start FARO TrackerPad. *For more information, see "TrackerPad" on page 118.*

Drive Beam

Click the DRIVE BEAM button to move the FARO Laser Tracker Measuring Head's laser beam. Click a button for the following drive options:

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.

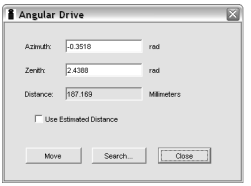
2 Slowly drag the mouse in any direction until the Laser Tracker Measuring Head is pointing near the target. Use the arrow keys to direct the beam.

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.

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.

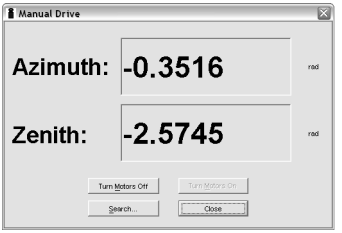
2 Click the MOVE button to move the laser beam to the position. Repeat until the laser beam is pointing near the target.

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.

To use the Manual Drive option:



1 Click the TURN MOTORS OFF button to switch the motors off.

2 Carefully move the Laser Tracker Measuring Head and move the laser beam near the target.

3 Click the TURN MOTORS ON button.

4 Click the SEARCH button to acquire the target.

5 Click the CLOSE button to exit the command.

Camera: Move the laser beam to a target using the FARO TargetCAM accessory. For more information, see the TargetCAM section of the FARO Laser Tracker Accessories Manual.

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 FARO Laser Tracker's settings.

Measurement Mode: Choose a mode. The samples (individual laser measurements of the SMR position) are best fit into a single 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 FARO Laser Tracker 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 FARO Laser Tracker 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 FARO Laser Tracker's CLOSURE dialog box. The CLOSURE dialog box shows the distance from the target to the Home position. 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.

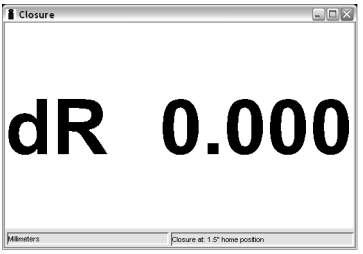


Figure 12-2 Closure Window

Environment Check

Click the ENVIRONMENT CHECK button to start the Operation Checks. *For more information, see "Operational Checks" on page 55.*

Disconnect

In the list of devices, select a FARO Laser Tracker and click the DISCONNECT button to disconnect it from CAM2 Q. Use the ADD NEW DEVICE button to search for devices connected to your computer. *See "Add a Device" on page 102.*

Manage Devices

The MANAGE DEVICES command accesses the DEVICE MANAGER panel and configure the device properties of the Laser Tracker. For more information, see the *Manage Devices* section of the *Devices* chapter in the CAM2 Measure 10 manual.

Move Device

The MOVE DEVICE command accesses the MOVE DEVICE POSITION wizard and perform measurements to move your Laser Tracker 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 10 manual.

Tracker Group

The TRACKER group contains all the commands necessary to interface with your FARO Laser Tracker using CAM2 Measure. For more information, see the *Tracker* section of the *Devices* chapter in the CAM2 Measure 10 manual.

Adding Readings

Use commands to control the Laser Tracker instead of hardware buttons. Buttons (and their associated hot keys) on the MEASUREMENT panel are used for recording a reading (G), recording an end click (H), and removing the last reading (Backspace).

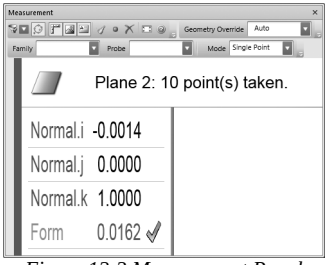


Figure 12-3 Measurement Panel

For more information, see the *Measurement Panel* section of the *Measure* chapter in the CAM2 Measure 10 manual.

Survey

SURVEY is a Laser Tracker specific command in CAM2 Measure 10. 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 10 manual.

Chapter 13: Configuring the FARO Laser Tracker ION in CAM2® Q

The DEVICE CONTROL panel contains all the commands for configuring a measuring device. In CAM2 Q choose DEVICE < DEVICE CONTROL PANEL to show the panel. You can also press the P hot key on the keyboard.

Device Control Panel

The DEVICE CONTROL panel appears when CAM2 Q is launched, 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.

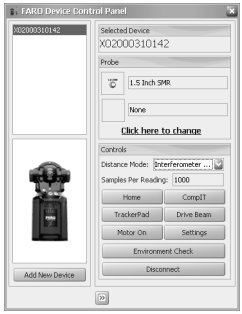


Figure 13-1 Device Control Panel

Choose a FARO Laser Tracker 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 FARO Laser Tracker's IP address and click CONNECT.

NOTE: The default IP address for a FARO Laser Tracker is 128.128.128.100.

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 FARO Laser Tracker 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.

Probes

The Probes section of the DEVICE CONTROL panel shows the current SMR and Adapter for the current FARO Laser Tracker.

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.

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 FARO Laser Tracker.

Distance Mode: Choose a distance mode.

Samples Per Reading: Enter a value. The number of individual laser measurements of the SMR position for each reading in a measurement. 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 Home position.

CompIT

Click the CompIT button to start FARO CompIT. *For more information, see "FARO CompIT" on page 63.*

TrackerPad

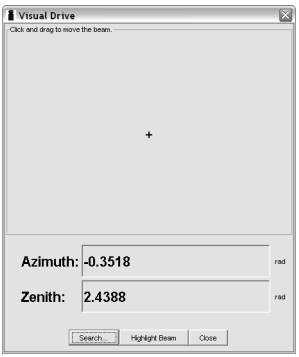
Click the TRACKERPAD button to start FARO TrackerPad. *For more information, see "TrackerPad" on page 118.*

Drive Beam

Click the DRIVE BEAM button to move the FARO Laser Tracker Measuring Head's laser beam. Click a button for the following drive options:

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.

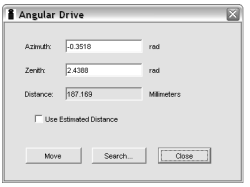
2 Slowly drag the mouse in any direction until the Laser Tracker Measuring Head is pointing near the target. Use the arrow keys to direct the beam.

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.

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.

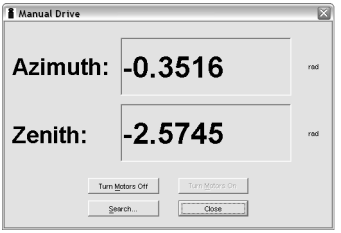
2 Click the MOVE button to move the laser beam to the position. Repeat until the laser beam is pointing near the target.

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.

To use the Manual Drive option:



1 Click the TURN MOTORS OFF button to switch the motors off.

2 Carefully move the Laser Tracker Measuring Head and move the laser beam near the target.

3 Click the TURN MOTORS ON button.

4 Click the SEARCH button to acquire the target.

5 Click the CLOSE button to exit the command.

Camera: Move the laser beam to a target using the FARO TargetCAM accessory. For more information, see the TargetCAM section of the FARO Laser Tracker Accessories Manual.

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 FARO Laser Tracker's settings.

Measurement Mode: Choose a mode. The samples (individual laser measurements of the SMR position) are best fit into a single 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 FARO Laser Tracker 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 FARO Laser Tracker 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 FARO Laser Tracker's CLOSURE dialog box. The CLOSURE dialog box shows the distance from the target to the Home position. 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.

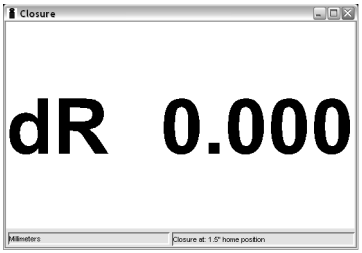


Figure 13-2 Closure Window

Environment Check

Click the ENVIRONMENT CHECK button to start the Operation Checks. *For more information, see "Operational Checks" on page 55.*

Disconnect

In the list of devices, select a FARO Laser Tracker and click the DISCONNECT button to disconnect it from CAM2 Q. Use the ADD NEW DEVICE button to search for devices connected to your computer. *See "Add a Device" on page 109.*

Chapter 14: Configuring the FARO Laser Tracker ION in CAM2 Measure

NOTE: This chapter describes the operation of your ION with CAM2 Measure v4.0 and X. For later versions of CAM2 Measure, see *"Configuring the FARO Laser Tracker ION in CAM2 Measure 10" on page 101*.

The DEVICES menu contains all the commands used to configure a measuring device. These commands are also available on the Devices toolbar and the Device Position toolbar.

Device Setup

Select DEVICES < DEVICE SETUP from the DEVICES menu. Choose a primary input measuring device from the DEVICE SETUP dialog box. The default device is the ION. To change the primary input device, select the device name and click the START button. This establishes communications with the selected device.

CAM2 Measure attempts to initialize communication with the primary input device. The settings file does not include a startup device.

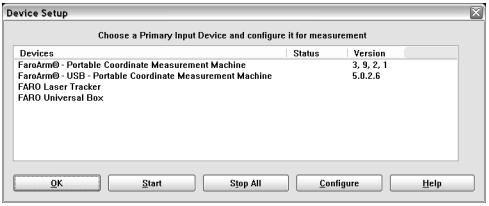
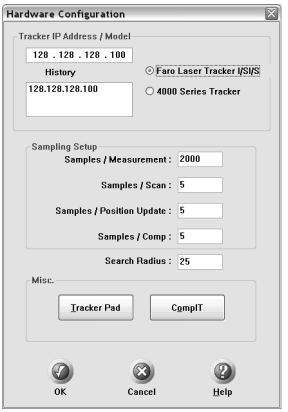


Figure 14-1 Device Setup dialog box

Hardware Configuration

Select DEVICES < HARDWARE CONFIG. In the HARDWARE CONFIGURATION dialog box you can:



- View the current IP Connection that CAM2 Measure will use to communicate with the ION.
- Set the Samples per Measurement.
- Set the Samples per Scan.
- Set the Samples per Position Update.
- Set the Samples per Comp.
- Set the Search radius.
- Access the Tracker Pad.
- Access the CompIT routine.

Click OK to accept the changes. Click the CANCEL button to discard any changes and exit the command. Changes made in the HARDWARE CONFIG dialog box are saved.

Tracker IP Address/Model: Enter the IP address of the Laser Tracker System. The History area lists any previously used IP address. Choose the model of your FARO Laser Tracker.

Samples/Measurement: The number of measurement samples for each measurement in Single Point Mode. Each measurement is an average of the samples.

Samples/Scan: The number of measurement samples for each measurement in Scan Mode. Each measurement is an average of the samples.

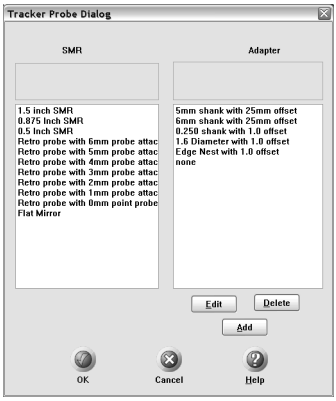
Samples/Position Update: The number of samples between position updates in any CAM2 Measure DRO window.

Samples/Comp: The number of samples for a compensation point at the end of a measurement command. The compensation point determines the direction of probe compensation for a feature measurement.

Search Radius: The size of the searching radius during a Survey. *For more information, see "Survey" on page 123.*

Probes

Select DEVICES < PROBES. In the PROBES dialog box you can:



- Select the diameter SMR or Retroprobe stylus diameter.
- Select an adapter to use with the selected SMR.
- Add a new probe.
- Edit an existing custom probe.

Edit Probe

Click the EDIT button in the PROBES dialog box to modify the details of the current probe. Change the name, height, offset, or units settings and click the OK button to accept the changes. Click the CANCEL button to discard the changes and exit the command.

NOTE: You cannot edit the default probes and adapters.

To create a new probe:

1 Click the ADD button in the PROBES dialog box.

2 In the SMR SIZE drop-down box, choose the SMR size for the new adapter.

3 Enter a name in the NAME box.

4 In DIMENSIONS, enter the correct height and offset for the new adapter.

5 Choose the units for height and offset.

6 Click OK to accept the new adapter. Click the CANCEL button to exit the command.

NOTE: In CAM2 Measure, “P” is the Hot Key for the PROBES command. See the CAM2 Measure software manual for more information about Hot keys.

Laser Tracker Menu

The LASER TRACKER menu contains the unique commands for the ION.

TrackerPad

Select DEVICES < LASER TRACKER < TRACKER PAD. In the TRACKERPAD dialog box, you can:

- Initialize the Laser Tracker System.
- Point the Laser Tracker Measuring Head to the specified reset location.
- Turn the Tracker motors Off/On.
- Turn tracking Off/On.
- Switch the Laser Tracker Measuring Head into backsight or frontsight measurement.
- Initiate a search for a target.
- Highlight the beam.
- Specify a drive option.
- View and configure the weather measurement settings.
- View the temperature sensor configuration and change each sensors alarm settings.
- View the bubble level.
- Manually set a distance to the target.

Initialize: Runs the angular encoder initialization sequence. This is necessary if the motors shut down and can not be turned back on with the TURN MOTORS OFF button. The Laser Tracker Measuring Head motors will shut down as a protective measure if the axis is forced or over-torqued.

Home: Points the Laser Tracker Measuring Head to the reset location.

Motors Off: Switches the motors off. If off, switches the motors on.

Turn Tracking Off: Switches the tracking of the laser off. If off, switches the tracking on.

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

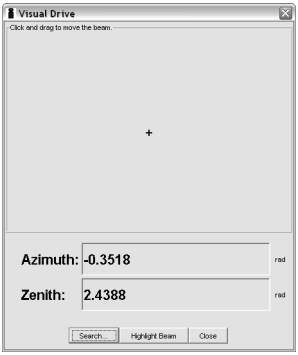
Search: Initiates a search for a target.

Highlight Beam: Moves the laser beam in a brief rotation.

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

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.

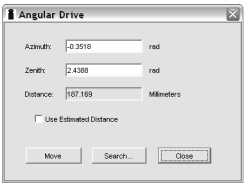
2 Slowly drag the mouse in any direction until the Laser Tracker Measuring Head is pointing near the target. Use the arrow keys to direct the beam.

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.

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.

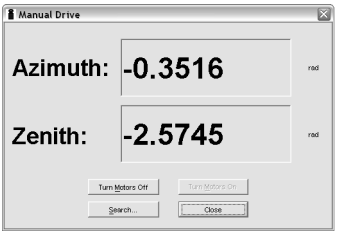
2 Click the MOVE button to move the laser beam to the position. Repeat until the laser beam is pointing near the target.

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.

To use the Manual Drive option:



1 Click the TURN MOTORS OFF button to switch the motors off.

2 Carefully move the Laser Tracker Measuring Head and move the laser beam near the target.

3 Click the TURN MOTORS ON button.

4 Click the SEARCH button to acquire the target.

5 Click the CLOSE button to exit the command.

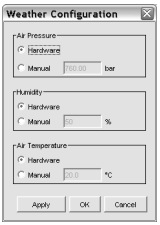
Weather Settings: Select and configure the source for the weather information. The HARDWARE option uses the Laser Tracker System's integrated weather station. The MANUAL option uses the entered weather information.

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.

Temperature Sensor Configuration: View and configure any temperature sensors connected to the MCU.

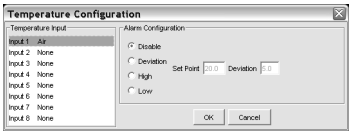
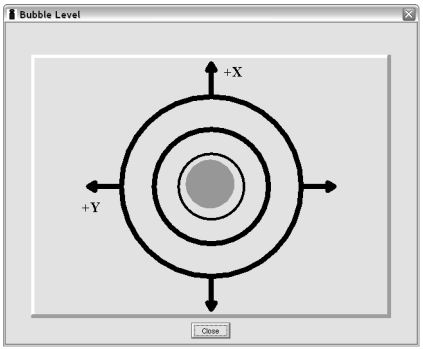
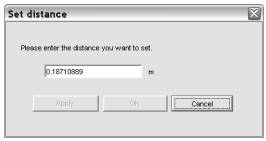


Figure 14-2 Temperature Sensor Configuration dialog box

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



Set distance: Enter the distance to a location.



To use the set distance option:

1 Acquire a target with the Laser Tracker Measuring Head.

2 Move the target to a location.

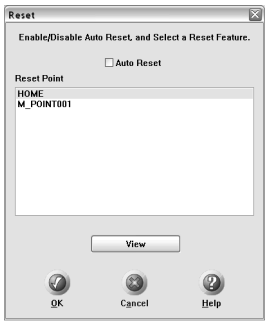
3 Enter the distance.

4 Click the APPLY button to accept 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.

Manage Reset Points

Select DEVICES < LASER TRACKER < MANAGE RESET POINTS. In the MANAGE RESET POINTS dialog box, you can:



- Enable or disable the Auto Reset feature.
- Select a Reset Point feature.
- View selected Reset Point feature on screen.

To set the Reset Point:

1 Choose the feature.

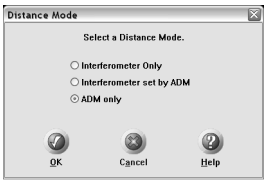
2 Click OK to assign the new reset location.

Create Reset Point

Select DEVICES < LASER TRACKER < CREATE RESET POINT. The screen displays a message to measure a point. For information on point measurements, see the CAM2 Measure Users Manual.

NOTE: This command does not automatically assign the point as the current Reset Point. To set the point as the new reset location, use the Manage Reset Points command. *See "Manage Reset Points" on page 121.*

Set Distance Mode



Select DEVICES < LASER TRACKER < SET DISTANCE MODE. In the SET DISTANCE MODE dialog box you can:

- Set the distance mode to Interferometer Only, Interferometer Set by ADM, or ADM Only.

Interferometer Only: This mode uses only the interferometer laser for distance measurements. If the Laser Tracker Measuring Head loses acquisition of the target, use the RESET command to re-acquire the target. *See "Reset" on page 122.* You can also re-acquire the target at the TMR (Tracker-Mounted Reset) by running the HOME command on the Tracker pad.

Interferometer Set by ADM: This mode uses the interferometer laser for distance measurement. If the Laser Tracker Measuring Head loses acquisition of the target, the target can be re-acquired using the ADM. Once the distance to the target is set with the ADM laser, distance measurement resumes using the interferometer laser. This eliminates using the RESET command. *See "Reset" on page 122.*

ADM Only: This mode uses only the ADM laser for distance measurements. If the Laser Tracker Measuring Head loses acquisition of the target, the target can be re-acquired using the ADM. This eliminates using the RESET command. *See "Reset" on page 122.*

NOTE: In CAM2 Measure, "N" is the Hot Key for the SET DISTANCE MODE command. See the CAM2 Measure software manual for more information about Hot keys.

Reset

Select DEVICES < LASER TRACKER < RESET. The Laser Tracker Measuring Head will move to the current Reset Point location.

NOTE: In CAM2 Measure, "T" is the Hot Key for the Reset command. See the CAM2 Measure software manual for more information about Hot Keys.

Aim

Select DEVICES < LASER TRACKER < AIM. In the AIM dialog box you can:

- Select a feature for Aim.

  To use the AIM command:

  1 Choose a feature in the AIM dialog box. The laser beam moves to the features position. If the Laser Tracker Measuring Head does not acquire the target, run the SEARCH command.

  2 Click the OK or CANCEL buttons to exit the command.

Search

Select DEVICES < LASER TRACKER < SEARCH. Selecting this command initiates a target search. The laser beam will automatically move in a circular pattern and search for a target.

Survey

Select DEVICES < LASER TRACKER < SURVEY. A Survey is an automatic measurement of a group of features.

NOTE: In this command, all of the targets for each location must be the same type.

In the Survey dialog box you can:

- Enter the settings for a new survey.

- Select a previous survey.

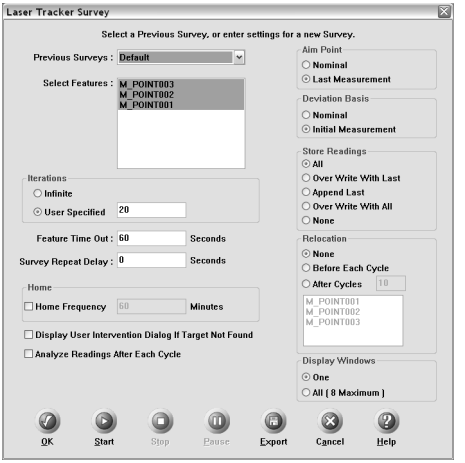


Figure 14-3 Survey dialog box

Previous Surveys: Click the down arrow to choose any previous survey. Choosing a previous survey loads the settings into the dialog box and is often a good starting point for a new survey.

Select Features: Choose the features for the survey.

Iterations: The number of times the group of survey features is measured. Choose INFINITE, or USER SPECIFIED and enter a number.

- Infinite - Measures the group of features until you click the STOP button in the LASER TRACKER SURVEY dialog box.
- User Specified - Measures the group of features and stops after the last iteration is complete.

Feature Time Out: Enter a time, in seconds, for the Laser Tracker Measuring Head to remain at a feature location to wait for the target.

Survey Repeat Delay: Enter a delay time between the end of an iteration and the start of the next iteration.

Home Frequency: Select the HOME FREQUENCY check box and enter a time, in seconds. This sets how often the Laser Tracker Measuring Head resets to Home. In ADM mode, the Home command runs an auto-adjust to retain the highest ADM accuracy.

NOTE: If you choose select the Home Frequency option, there *must* be a target present at the Home location during the survey.

Display User Intervention Dialog If Target Not Found: Select this check box to display a message when a target is not found.

Analyze Readings After Each Cycle: Select this check box to display the ANALYZE READINGS dialog box after a Cycle, the measurement of the selected features, is completed. You can accept or reject the readings from the Cycle.

Aim Point: Choose the Aim point.

- Nominal - For each feature, the laser beam aims at the location of the associated nominal of the feature.
- Last Measured - For each feature, the laser beam aims at the features last measured location.

Deviation Basis: Choose the measurement deviation reporting option.

- Nominal - For each feature, the deviation value is the comparison of the measurement and nominal values.
- Last Measurement - For each feature, the deviation value is the comparison of the measurement and the last measurement value.

Store Readings: Choose a storage option for the measurements, or readings, for the group of features. Use the REVIEW FEATURES command to view the readings for any feature.

- All - All measurements add readings to each feature in the current file.
- Over Write With Last - The last measurement adds a reading to each feature, and replaces all existing readings in the current file.
- Append Last - The last measurement adds a reading to each feature in the current file.
- Over Write With All - All measurements add readings to each feature, and replaces all existing readings in the current file.
- None - None of the Survey measurements add to the current file.

Relocation: Choose an option for a relocation. A relocation uses a set of measurements to define a new Device Position.

- None - No relocation.
- Before each Cycle - Choose three or more features from the list for the relocation. Before measuring the survey group of features, these features create a Device Position.
- After Cycle - Choose three or more features from the list for the relocation, and enter a number. After the number of cycles is complete, these features create a Device Position before measuring the next survey group of features.

Display Windows: Choose the option for the Digital Readout Windows. During the measurement of the group of features, a DRO window(s) opens.

- One - a single DRO window opens and the shows the data from the current measurement.
- All - A DRO window opens for each feature. The maximum number windows is eight (8).

To begin a survey:

1 Measure the points for the survey.

2 Select DEVICES < LASER TRACKER < SURVEY.

3 Choose features for measurement in the SELECT FEATURES window.

4 If necessary modify the options in the LASER TRACKER SURVEY dialog box.

NOTE: Select a previous survey from the PREVIOUS SURVEYS drop-down box.

5 Click the START button to begin measuring the features.

- Click the PAUSE button, at any time, to pause the command after a measurement cycle is completed. Click the Start button to begin the next cycle.

6 After you click the STOP or PAUSE button, or the number of iterations is complete, click the EXPORT button to save the measurement data to a text file.

NOTE: Readings marked unused do not export.

7 Click the OK button to complete the command. The Readings for each feature are modified according to the selected STORE READINGS radio button.

8 Click the “X” in the upper right-hand corner of the LASER TRACKER SURVEY dialog box, or the CANCEL BUTTON to end the command and discard any measurements.

Interferometer Check

Select DEVICES < LASER TRACKER < INTERFEROMETER CHECK to run the interferometer check (optional IFM only). The Closure window shows the distance from the target to the Home position. *See "Manage Reset Points" on page 121.*

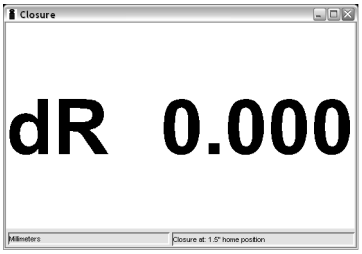


Figure 14-4 Closure Window

NOTE: Optional IFM only.

Operational Checks

Select DEVICES < LASER TRACKER < OPERATIONAL CHECK. This command starts the Operation Checks for the ION.

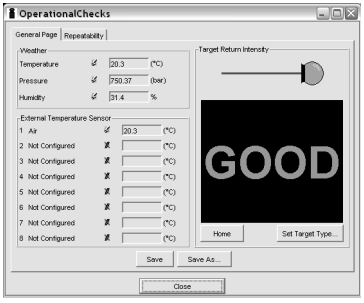


Figure 14-5 Operational Checks dialog box

For more information, see "Operational Checks" on page 55.

Technical Support

FARO Technologies, Inc. is committed to providing the best technical support to our customers. Our Service Policy is detailed 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:
  866-874-1154

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

Asia:
1800 511 1360, +65 6511 1350 (Worldwide)

Japan:
+800 6511 1360, +81 561 63 1411 (Worldwide)

China:
+800 6511 1360, +86 21 6191 7600 (Worldwide)

India:
000800 650 1397, +91 11 4167 6330/1 (Worldwide)

- **Fax**
  North America:
  +1 407 333 8056
  Europe:
  +800 3276 1737, +49 7150 9797-9400 (Worldwide)

  Asia:
  +65 6543 0111

  Japan:
  +81 561 63 1412

  China:
  +86 21 6494 8670

  India:
  +91 11 4167 6332

- **E-Mail**
  North America:
  support@faro.com

  Europe:
  support@faroeurope.com

  Asia:
  salesap@faro.com

  Japan:
  support_japan@faro.com

  China:
  chinainfo@faro.com

India:
infoindia@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 detailed 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 “Licenser”) 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 Licenser 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, sub-license, rent or lease the software to any third party without the Licenser’s prior written consent.

II. The Licenser 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-Licenser 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 Licenser’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 Licenser.

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 LICENSER 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 majuere, 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 ION and reported to FARO within the Maintenance/Warranty Period. If the ION 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 ION will be repaired or adjusted to the extent found by FARO to be necessary or at the option of FARO, replaced with a new ION 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 ION. Within a reasonable time of receipt of such notice, FARO shall have the System and ION diagnosed by its service personnel, and maintenance/warranty service will be provided at no cost to the Purchaser if the System and

ION 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 ION 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 ION, 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 ION’s (“Temporary Replacements”) while corresponding parts of the Purchaser’s system

or ION are undergoing repair at FARO's factory. Shipping charges for these "Temporary Replacement" parts or ION'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.

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 ION 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 ION 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 ION, 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 ION, 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 ION, 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 ION, the Software, operating manuals and any other product or merchandise sold pursuant to the Order. If the Purchaser is buying only a ION, 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 ION, the Software, the Computer, and optional parts and accessories associated with the ION.

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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