Customer FAQs

TRIMBLE GEOSPATIAL
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Trimble R12i GNSS System Frequently Asked Questions

What is the difference between the new Trimble TIP technology and the legacy Trimble SurePoint tilt compensation technology found in the Trimble R10 and R12?

Trimble® TIP™ technology uses an Inertial Measurement Unit (IMU) comprised of three accelerometers and three gyroscopes to provide the necessary information for the positioning engine to precisely determine the attitude of the rover, allowing the tilt heading and thus the position of the pole tip to be computed in real time.

On the other hand, Trimble SurePoint™ technology, first introduced in the Trimble R10, uses a magnetometer to determine the tilt heading. Because the heading provided by the magnetometer depends on an accurate global model of the earth's magnetic field, and because the sensor itself is susceptible to local sources of magnetic interference which can render it unusable, the achievable tilt angle is less (15°), compensated points cannot be measured in all instances, and the system must remain static when measuring a compensated point. It is therefore also not possible to use Trimble SurePoint technology for stakeout, whereas Trimble TIP technology doesn't require the system to remain static and is therefore suitable for both measurement and stakeout workflows.

Finally, because Trimble TIP technology uses sensor data to automatically align the IMU to the GNSS reference frame in the field, it is not necessary to perform specific steps to calibrate the sensors, as is the case with the Trimble R10 and Trimble SurePoint technology.

Are there differences in the GNSS performance of the R12i and R12? Do they both use ProPoint technology?

The Trimble R12 and R12i both use the ProPoint GNSS positioning engine, and indeed Trimble TIP technology cannot integrate with previous generations of Trimble GNSS positioning engines as ProPoint is an entirely new generation of software architecture with TIP integration as part of the fundamental design. Trimble ProPoint technology also delivers the robustness required to maintain alignment of the combined GNSS-inertial solution when using TIP technology in challenging GNSS environments. This is applicable for both RTK and CenterPoint RTX surveys.

However, there is one area where the GNSS performance of the R12 and R12i differs which users should be aware of, particularly when working in challenging GNSS environments. When using the *Topo point* method with the Trimble R12, the ProPoint positioning engine delivers a *converging* antenna phase center (APC) position solution. This is particularly useful when attempting to measure a point in a challenging environment such as under tree canopy, as the system is able to gradually improve its solution quality once the antenna can be assumed to be stationary. On the

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other hand, when using the ***Topo point*** method with the Trimble R12i and TIP tilt compensation technology, the APC position solution is *non-converging*, meaning that the system won't always be able to achieve sufficient precision to meet the point thresholds. It is therefore suggested that Trimble R12i users either select the ***Observed control point*** method or else disable IMU tilt compensation to have the best possibility of obtaining a result if they are finding that the system is struggling to achieve the required level of precision in challenging GNSS environments.

Can the Trimble R12 be upgraded to support Trimble TIP technology?

No. There is a fundamental difference between R12 and R12i hardware: the Trimble R12i is equipped with an Inertial Measurement Unit (IMU), a collection of highly accurate sensors which cannot be installed in a Trimble R12 once it has left the factory.

Which types of real-time GNSS corrections does Trimble TIP technology support?

Trimble TIP technology is supported with most real-time corrections types for survey:

- Single baseline (SBL) RTK, whether delivered via UHF or IP
- Trimble VRS Now™ network RTK
- Trimble xFill®, which provides continuous operation during gaps in the primary GNSS correction stream
- Trimble CenterPoint® RTX, which provides RTK-level positioning performance worldwide with no need for a local base station or cellular network coverage

Whatever the correction type, Trimble recommends using all available GNSS constellations and signals—as determined by the contents of the correction message—in order to give the R12i rover the most amount of data to work with.

Does my RTK base station need to be updated to the new RTK GNSS engine (Trimble ProPoint technology) in order to work with the Trimble R12i rover?

No, the RTK base station is not required to run firmware with Trimble ProPoint™ technology (recall that the RTK processing happens at the rover). However, it is recommended to use a modern RTK base station (unless using VRS network RTK or Trimble CenterPoint RTX) capable of tracking and broadcasting all available GNSS constellations and signals to the rover to fully utilize the capabilities of the Trimble ProPoint positioning engine and Trimble TIP technology.

Note that Trimble RTX and Trimble VRS Now networks are supporting all available GNSS constellations with some regional dependency; ensure that the correct mountpoint is selected.

What is the process to begin using IMU tilt compensation after starting a survey?

To begin using IMU tilt compensation after starting a survey with real-time GNSS corrections, all that is necessary is to provide the system with sufficient motion—i.e. dynamic IMU sensor data—to compute a full position and attitude solution, a process commonly referred to as ***alignment***. This is generally a straightforward process that happens automatically while the user moves to their first point, but the user can also align the system on the spot by providing sufficient motion, e.g. by tilting the system in orthogonal directions. There are multiple indicators in the Trimble Access™ user interface that tell the user when the system is aligned.

What makes the receiver lose alignment and what do I have to do to realign?

The Trimble R12i generally will not lose alignment as long as the IMU is provided with sufficient dynamics, which will typically be the case when a surveyor is using the system in the field. Alignment *can* be temporarily lost if the IMU sensors are *saturated*, which is caused either by a large g-force, i.e. a physical shock to the system, or else by a high rate of angular velocity, which can be induced e.g. by spinning the rover about its vertical axis. In addition, extended

periods of very little motion, but without being entirely stationary, can also cause a loss of alignment, but this is less likely during typical survey operation. In any event, if alignment is truly lost at any point during the course of a survey then all the user needs to do in order to realign the system is provide sufficient dynamics, i.e. motion, to the IMU.

One benefit of Trimble TIP technology relative to its competitors is that the system will detect if the pole tip becomes static and will freeze the heading alignment until the system moves again. What this means is that the user is free to set their system aside while performing another task and that—as long as the receiver maintains good GNSS satellite reception—the system will still be aligned when the user picks up the system to resume their work. Keep in mind that re-alignment is such a trivial operation that there is usually no need to take particular care to maintain an alignment when the system is not in continuous use.

Will the R12i get RTK initialization without aligning the IMU?

While the R12i technically has the ability to provide the antenna phase center (APC) position solution while TIP tilt compensation is enabled (which is in fact what the system does when switching from topo or rapid point methods to the observed control point method), the APC position is not otherwise reported unless IMU alignment is lost or IMU tilt compensation is disabled. Nevertheless, RTK will indeed initialize even when the IMU is not aligned.

What is the maximum allowable tilt angle with Trimble TIP technology?

Although Trimble has not verified the stated positioning performance at tilt angles greater than 30°, there is no hard limit on the allowable tilt angle with Trimble TIP technology. As a general principle, the primary limiting factor when taking tilted measurements is GNSS satellite reception; if the receiver is tilted such that GNSS signal reception is inhibited then the solution quality will begin to degrade. Users should always exercise caution and perform additional checks when measuring points with tilt angles above 30°.

Why is only the horizontal performance specified for Trimble TIP technology?

The reason that horizontal positioning performance is specified for Trimble TIP technology, while vertical positioning performance is equivalent to regular RTK (or CenterPoint RTX), is that the vertical position is not a function of the IMU heading, which will always be the least precise element of the attitude solution. The tilt magnitude (pitch & roll), by contrast, is relatively simple to observe directly and to a good degree of precision, meaning that the effect on vertical positioning performance is essentially negligible.

Why does the tilted positioning performance specification have both constant and tilt-dependent components?

The positioning performance specification for TIP tilted surveying has a constant component to account for the effect of residual error in the alignment between the IMU and the receiver housing, which is precisely determined in manufacturing, and a tilt-dependent component which accounts for uncertainty in the IMU heading within the GNSS reference frame.

The value of 5 millimeters for the constant component is the largest potential error that would be anticipated, assuming the receiver is mounted on a 2 meter fixed-length survey pole and quick release adapter which are mechanically straight, although manufacturing data suggests that most R12i receivers will exhibit less than 5 millimeters of error due to residual IMU misalignment.

The tilt-dependent component grows with increasing tilt angle due to the fact that the IMU heading uncertainty will contribute more to the horizontal pole tip position uncertainty the more the tilt angle grows. This is the reason that the allowable tilt angle with the Trimble R10 and R12 receivers, which use a less precise magnetometer to determine heading, is limited to 15°, whereas the R12i supports tilt angles of 30° or more. However, because the heading precision is a function of the overall solution quality, the value of 0.4 mm/° of tilt assumes a good GNSS environment and a well-aligned GNSS-inertial solution.

Why is it recommended to use a fixed-length range pole with the R12i?

It is recommended to use a fixed-length range pole with the Trimble R12i in order to minimize the potential for additional position errors caused by mechanical deflection in the pole. Recall that any misalignment between the IMU and the receiver body frame will result in a separation between the computed pole tip position and the physical pole tip, so every effort should be made to minimize the potential for such errors in order to achieve the most accurate and repeatable measurement results.

Which measurement methods in Trimble Access support the use of a tilted pole when IMU tilt compensation is enabled?

When IMU tilt compensation is enabled, the *Topo point* and *Rapid point* measurement methods in Trimble Access both support the use of a tilted pole. This also applies to related measurement workflows including *Continuous topo*, *Measure codes*, *Measure to surface*, and *Site calibration* (when the *Topo point* method is used to measure a calibration point). The only measurement type that does not support the use of a tilted pole when IMU tilt compensation is enabled is the *Observed control point* method, which is discussed below.

What is the difference between a Topo point measurement taken with IMU tilt compensation enabled and one taken using GNSS only—i.e. with tilt compensation disabled?

A topo point measurement taken with GNSS only, i.e. with IMU tilt compensation disabled, produces a solution with a static converging antenna phase center (APC) position, meaning that the solution quality will usually improve with time if the system is left to collect static measurements. With IMU tilt compensation enabled, the topo point measurement method doesn't produce a converging static APC position solution. Therefore, users attempting to achieve the best possible measurement precision, particularly in challenging GNSS environments, should either disable IMU tilt compensation and measure using GNSS only, or else switch to the observed control point method, which provides a converging APC position solution while preserving IMU alignment.

Why is it not possible to use the Observed Control Point measurement method with a tilted pole?

The *Observed control point* method is usually employed when the best possible measurement results are desired. Since there will always be some amount of additional error when using IMU tilt compensation vs. using GNSS-only and plumbing the pole, the decision was made when designing the measurement workflows to limit support for tilt compensation to the *Topo point* and *Rapid point* measurement methods.

In order to make transitioning between observed control point and other measurement methods as seamless as possible, the system was implemented in such a way that it is not necessary to disable IMU tilt compensation to measure an observed control point. Instead, when the user selects the *Observed control point* method while IMU tilt compensation is enabled, the positioning engine will provide a converging APC position solution in place of the usual pole tip position output. Once the user reverts back to the *Topo point* or *Rapid point* method or switches to stakeout mode, the system once again reports the pole tip position, allowing the user to resume working with a tilted pole after measuring an observed control point without needing to first re-enable IMU tilt compensation or realign the IMU.

Does the R12i with IMU tilt compensation enabled produce a pole tip solution or an APC solution?

With IMU tilt compensation enabled, the R12i will provide a position solution for the pole *tip*. The lone exception is when the user selects the *Observed control point* measurement method. In this situation, the receiver will output the position of the APC, allowing Trimble Access to calculate the position of the pole tip by subtracting the pole length (plus APC offset), thereby eliminating the IMU from the observation. Of course, this only works when the pole can be assumed to be perfectly plumb, which is why Trimble Access displays the eBubble and reminds the user to level the system when measuring an observed control point with IMU tilt compensation enabled.

What is the effect of changing the antenna height after a point has been stored?

While not an obvious consideration, the pole length (or antenna height) factors into the estimated system attitude when IMU tilt compensation is enabled. This is why, for example, the IMU alignment is invalidated if the antenna height is changed during the course of a survey. What this means is that, by changing the antenna height after a point has been stored, there will still be some residual position error—proportional to the tilt angle—which cannot be entirely accounted for. If any critical points have been measured or staked out while using IMU tilt compensation with an incorrect antenna height it is advisable to return to those points to verify that the results meet the accuracy requirements for the job.

Is the R12i capable of outputting heading information for use with other software?

At this time there is no open data format that supports heading output from the R12i.

Is IMU tilt compensation supported with post-processed kinematic (PPK) surveys?

No. Because Trimble TIP technology relies on having a precisely aligned GNSS-inertial solution in order to provide accurate results when the survey pole is tilted, it is not practical to assume that the system will have sufficient sensor data to provide reliable post-processed kinematic survey results. However, the Trimble R12i does still support PPK surveys performed with the survey pole held plumb in the traditional manner.

Why is a pole tip solution better to use for stakeout compared to an APC solution?

The main advantages of staking out points with a pole tip solution rather than an APC solution are that it is faster and much less fatiguing for the user. Not only does the process of iteratively minimizing the stakeout deltas take more time than directly navigating the pole tip to the design point, it can also be a tiresome process for the surveyor, particularly on jobs that involve a lot of staking. Of all the ways in which the Trimble R12i with TIP technology saves the user time and effort in the field, these benefits are perhaps most appreciable when it comes to stakeout.

Does the orientation of the R12i matter when performing a stakeout with IMU tilt compensation enabled?

As long as the survey pole and quick release adapter are in good condition, meaning that any discrepancy between the computed pole tip position and the physical pole tip position will be minimal, then the orientation of the R12i will not matter when staking out points with tilt compensation enabled. However, it is important to remember that the receiver needs to be oriented with the LED panel facing the user in order for the graphical stakeout screen and the rover heading in the map screen to match with the user's orientation in their environment.

Does the R12i support use of the eBubble?

Yes, the eBubble remains an integral feature of the Trimble R12i, whether or not IMU tilt compensation is enabled.

With IMU tilt compensation enabled, the eBubble will automatically disappear from view when IMU alignment is attained, i.e. when it is not needed. Conversely, the eBubble will appear if IMU alignment is lost, thus serving as an additional indicator to the user that it is not currently possible to measure with the pole tilted. The eBubble also appears while IMU tilt compensation is enabled when the ***Observed control point*** method is selected, as tilted measurements are not supported by this method.

When IMU tilt compensation is disabled, i.e. when the system is switched to GNSS-only operation, the eBubble is displayed, but can be hidden if desired.

What are the different eBubble calibration methods and under what circumstances should one be chosen over the other?

With the Trimble R12i, there are now two eBubble calibration methods: ***Calibrate to vial*** and ***Calibrate to IMU***.

Calibrate to vial is the same calibration method that has been in use since the advent of the Trimble R10. This method requires a well-calibrated level reference, such as a tribrach or a survey pole calibrated on a jig, to align the tilt sensor with the local gravity vector. This traditional method has the advantage of providing a result which can always be precisely reproduced.

Calibrate to IMU is a new method which allows the eBubble to be calibrated to the vertical vector from the combined GNSS-inertial solution. The calibration process is the same in practice, but an aligned GNSS-inertial solution is needed before the calibration can be performed. Because the attitude solution is used to calibrate the eBubble in this workflow, it is important to ensure that the GNSS-inertial solution is well aligned.

Calibrating the eBubble to the IMU has the advantage of not requiring a level reference, allowing a user who is out on the jobsite to calibrate their system's eBubble without any special tools. Calibrating the eBubble to the IMU is also recommended when employing a pole bias adjustment, as this will align the eBubble to the adjusted vertical such that points measured with GNSS-only will be corrected for pole bias. If the eBubble is calibrated to the IMU because a pole bias adjustment has been applied, it is important to remember that the calibration is only valid for that particular receiver/pole/quick release adapter combination and that a new eBubble calibration must be performed if any of these system components is changed.

What is the purpose of the Pole bias adjustment, when should it be performed, and what type of results can be achieved?

The purpose of the *Pole bias adjustment* is to correct for position errors caused by gross mechanical misalignment in a particular survey pole and quick release adapter combination when used in conjunction with an R12i receiver and TIP tilt compensation technology.

If there is sufficient deflection from vertical along the length of the survey pole, the result will be a discrepancy between the *computed* pole tip position and the *physical* pole tip position. This can be easily observed by measuring the same point on the ground in two orientations 180° apart. This simple concept forms the basis of the *Pole bias adjustment* procedure, which uses a series of measurements in two orientations—separated by 180°—to compute roll and pitch angle corrections which can then be applied to the computed pole tip position to bring it into alignment with the physical pole tip position (within the level of RTK noise).

A pole bias adjustment should therefore only be performed if there is reason to believe that the survey pole and quick release adapter combination being used is not straight along its entire length. It follows also that a pole bias adjustment is only valid for a particular survey pole and quick release adapter combination. If the pole and/or quick release adapter is changed at any point then the pole bias adjustment should be cleared and a new set of correction values determined, if necessary.

It is important to note that pole bias adjustment corrections cannot be "backed out" or removed from points once they've been stored. It must also be emphasized that a pole bias adjustment is not a means of completely removing the additional error that comes with using IMU tilt compensation, as the procedure will only ever be able to resolve the corrections to the level of RTK noise, or about 4 millimeters. For this reason, it is suggested that pole bias adjustment correction values smaller than 5 millimeters can be discarded, while values of 5-10 millimeters should be accepted in order to achieve repeatable results no matter which direction the receiver is oriented when measuring a point. Correction values greater than 10 mm should serve as a warning to the user that the survey pole and quick release adapter combination being used may have significant mechanical deflection from vertical and should therefore be treated with caution.

I encountered an IMU bias error in Trimble Access. What does this mean for my system?

IMU sensor bias, measured in mG for accelerometers and degrees per hour for gyroscopes, is an inherent source of error affecting any IMU. The Trimble R12i IMU sensor biases are precisely determined for each individual sensor in

the factory through a calibration process, allowing for exceptional out-of-the-box performance. However, IMU biases can and do change over the life of the sensor due to three principal causes: aging, temperature changes, and physical shock.

Trimble TIP technology continually re-estimates the IMU sensor biases as part of the extended position and attitude solution, so gradual changes in the bias values are not an issue. However, if any of the IMU biases should increase—for whatever reason—beyond a set threshold, the receiver will send a message to Trimble Access indicating that a large bias change has been detected and that the biases need to be re-baselined. At this point, the user can either disable IMU tilt compensation and continue to work with GNSS only, or else complete a simple calibration procedure to re-baseline the sensor bias values. Once the sensor bias values have been reset, the user will be able to resume working with IMU tilt compensation enabled. If the problem persists, contact your Trimble distributor.

IMU integrity monitoring: how are age, shock and temperature being monitored and at what ranges?

As we've previously discussed, the inherent biases in the three accelerometers and three gyroscopes that comprise the IMU can and will change over the life of the receiver. These changes can be caused by physical shock to the receiver, changes in temperature, and sensor aging.

Rather than looking at the *cause* of IMU bias changes, Trimble TIP technology continually re-estimates the sensor bias *values* as part of the position and attitude solution and monitors for large changes, which can have an impact on the overall solution quality if left unaddressed. A sufficiently large change in any of the bias values will trigger a bias alert, prompting the user to take action to recover the system.

What version of Trimble Access supports the Trimble R12i receiver and which controllers are compatible with the Trimble R12i?

The Trimble R12i is supported by Trimble Access version 2020.10 running on Windows® 10 (Trimble TSC7, Trimble T10 tablet, Trimble T7 tablet) and Android-based (TDC600) controllers with full feature support.

For more information

For more information, contact your local Trimble distributor.