ASTERI X3 & GNSS Accuracy Explained

GNSS & GPS: How are they measured and what do they mean?

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Presented by
Tri-Global Technologies

Tri-Global is excited to announce the release of the Asteri X3i Mod3.

The Asteri X3i will move from a 392 channel GNSS receiver to an 800+ channel receiver!

See full specifications below.

- GPS, Glonass, BeiDou, and Galileo simultaneously
- BeiDou ACEBOC, Galileo ALTBOC, QZSS, IRNSS, and Atlas
- GPS L2P, L2C, L5, Glonass G2, G3, P2 and more frequencies
- 800+ channels
- 1 Hz standard, 10Hz, 20Hz, optional 50Hz update rate
- 60 seconds cold start
- 30cm SBAS, 4cm Atlas H10, 8 mm + 1ppm RTK

"Could you explain Global Positioning System (GPS) and Global Navigation Satellite System (GNSS) accuracy?

What do they mean and how are they measured?"

To do this, we have to discuss some statistical analysis theory. All GNSS manufacturers calculate accuracy the same way, but will often display different versions. The first thing to realize when discussing GPS is that ***"accuracy"*** technically refers to ***"precision."***

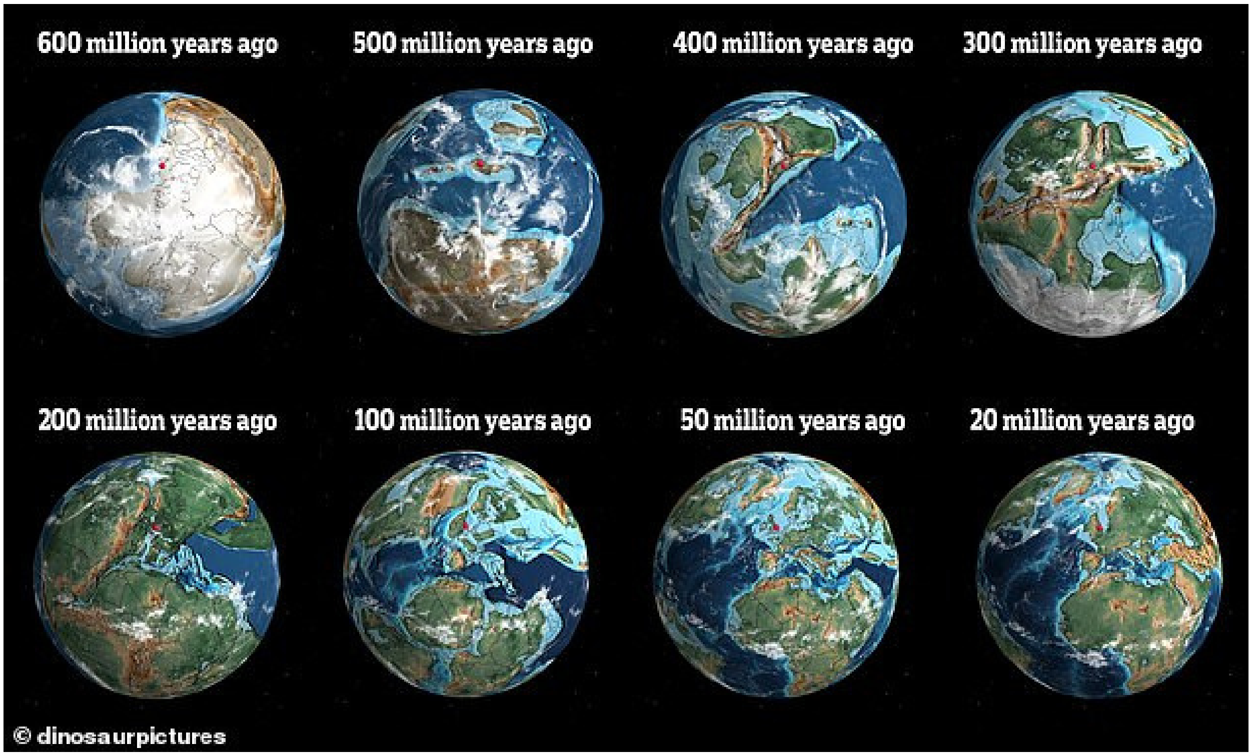
Think of a dart game; if you throw 5 darts and they all miss the dartboard, but all 5 darts are clustered within an inch of each other, your ***precision*** is great, but your ***accuracy*** needs improvement.

That's how GPS/GNSS works. Accuracy is a statistically calculated value of how well the positions fall in with each other within a certain observation period. That usually begs the question...

*"Why is that the value shared rather than how well the positions fall in with the world, or '**true accuracy**'?"*

There are a number of factors that influence this. First, we are not on a stable platform.

Our world is constantly moving and changing. Take a look at the graphic below to see how much our world has likely changed. Even though these changes took place over hundreds of millions of years, you get the idea.



The National Earthquake Information Center says the world has over 20,000 recorded earthquakes per year, or 55 earthquakes per day. Even if it is only by tiny fractions of a meter, our earth is changing 55 times per day. How do you determine how "accurate" a point is on an ever-changing surface? The answer is by setting a moving reference point.

In geographic terms, we call this a ***datum***, a geographical model that is frozen in time. With a GNSS receiver such as the Asteri X3i, we use a reference datum that corresponds with an International Terrestrial Reference Frame (ITRF). However, that can vary quite a bit from local references.

For instance, in the United States, most of our RTK networks use a reference datum called the North American Datum of 1983 (NAD 83). NAD 83 was created by reviewing over 250,000 different reference stations across the U.S. and freezing that information in time as of April of 2011.

Our next reference datum is supposed to be a 2025 datum, but will likely not be available until almost 2030. How accurate we are compared to the 2011 reference, originally created nearly 40 years ago, is going to depend on *where* you are, and importantly, *when* you are collecting.

In the US, the National Geodetic Society will publish an algorithm every few years to adjust between ITRF and our local datum. This is why GNSS is referencing “precision” rather than “accuracy,” because accuracy becomes more of an observation against an unknown reference point.

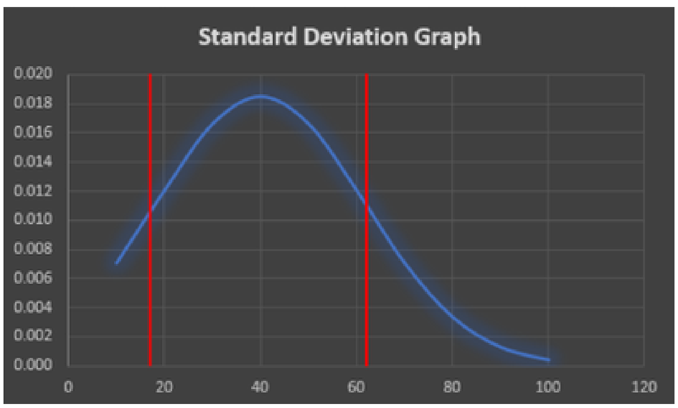
That brings us back to statistics. Remember when our teachers kept telling us the importance of the “bell” curve? This is exactly the foundation of how accuracy is determined.

The bell curve provides us with a tool to utilize standardized measurements and better inform us of the distance (or “deviation”) between the average (mean) and the data point. Because the normal curve always has a mean of zero and a so-called standard deviation of one, we can begin to understand accuracy in these terms or positions.

Utilization of a normal curve uniquely allows us to resolve accuracy through the use of standard deviations, abbreviated by the Greek letter Sigma (**σ**). In simple terms, 68% of the measurements we take will land within one standard deviation to the left and right of the overall mean. Two standard deviations will cover 95% of the measurements. Therefore, the smaller the dispersion (or distribution) of the data points, the more precise, despite the unit of measure. In effect, the tighter the distribution, the smaller the standard deviation and the better the position.

To illustrate, suppose we take an even distribution of grades between 0 and 100. We have an average of 40 (high point of the curve), with a standard deviation of 21.6 points. This means that 68% of the values on the bell curve fall between 18.4 on the low side of the average, and 61.6 on the high side of the average.

Grades	Normal Distribution		
10	0.007	Average:	40.0
20	0.012		
30	0.017	Standard Dev:	21.6
40	0.018		
50	0.017		18.4
60	0.012		61.6
70	0.007		
80	0.003		
90	0.001		
100	0.000		



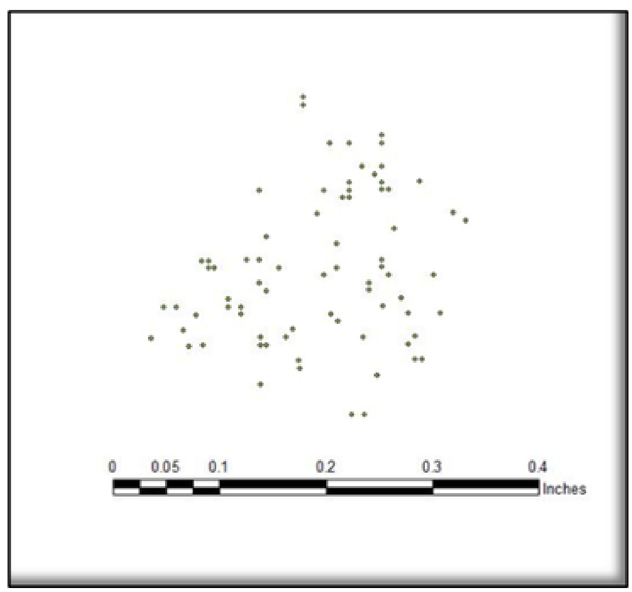
Now, let's take that and apply it to GNSS accuracy. On the right are some real world results of the Asteri X3i Mod3, collecting around 1 minute's worth of data on a second by second basis from our HPRTK correction service, plotted in a Georgia State Plane NAD 83.

It is pretty impressive that all positions are in a tight little ½ inch diameter, but let's look at how it relates to standard deviation and GNSS accuracy.

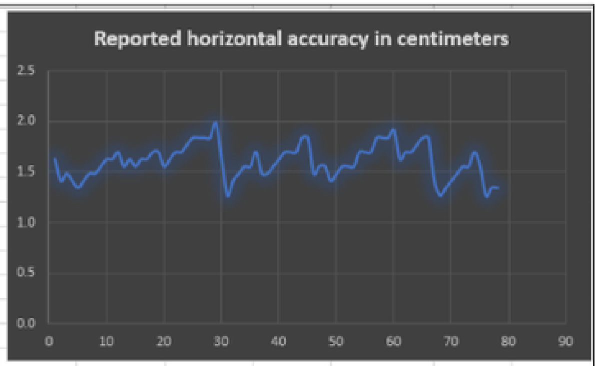
First, let's take a manufacturer's specification on the Asteri X3i Mod3. It states "accuracy" of 8 millimeter + 1ppm RTK. We are going to assume that our HPRTK network has a 50km baseline, so that adds about 5 millimeter to the 8 millimeter, so we will assume our RTK precision is stated at 1.3 centimeter.

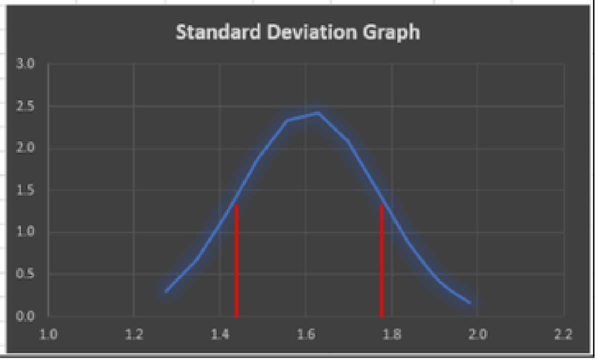
First we will look at the "accuracy" the device reported. Our device, like most, reports 1 sigma error in meters in latitude, longitude, and altitude. We try to simplify this data for our users by just displaying a "horizontal" value.

This value is actually a calculation of the combination of both latitude and longitude by using the Pythagorean theorem. On the next page is what the above data looked like graphically, and then on a standard deviation graph. So, essentially we had a 1.6 centimeter average reported (pretty close to the 1.3 centimeter) and a 1.6 millimeter standard deviation. That's pretty precise!



X	Y	H. Acc (cm)	H. Acc (cm)	Normal Distribution		
2537040.889	1426173.657	1.6	1.3	0.3	Average Reported Accuracy:	1.61
2537040.895	1426173.654	1.4	1.3	0.3	Standard Deviation:	0.162689
2537040.892	1426173.653	1.5	1.3	0.3		
2537040.889	1426173.656	1.4	1.3	0.7		1.44
2537040.898	1426173.65	1.3	1.3	0.7		1.77
2537040.9	1426173.648	1.4	1.3	0.7		
2537040.891	1426173.653	1.5	1.3	0.7		
2537040.895	1426173.653	1.5	1.4	1.2		
2537040.887	1426173.643	1.6	1.4	1.2		
2537040.886	1426173.646	1.6	1.4	1.2		
2537040.885	1426173.644	1.6	1.4	1.2		
2537040.885	1426173.649	1.7	1.4	1.2		
2537040.895	1426173.644	1.6	1.4	1.2		
2537040.891	1426173.645	1.6	1.4	1.2		
2537040.881	1426173.644	1.6	1.5	1.9		
2537040.881	1426173.643	1.6	1.5	1.9		
2537040.881	1426173.644	1.6	1.5	1.9		
2537040.882	1426173.643	1.7	1.5	1.9		
2537040.886	1426173.646	1.7	1.5	1.9		
2537040.879	1426173.638	1.6	1.5	1.9		
2537040.878	1426173.64	1.6	1.5	1.9		
2537040.88	1426173.639	1.7	1.5	1.9		
2537040.883	1426173.641	1.7	1.5	1.9		
2537040.879	1426173.64	1.8	1.6	2.3		
2537040.881	1426173.637	1.8	1.6	2.3		
2537040.884	1426173.64	1.8	1.6	2.3		
2537040.886	1426173.637	1.8	1.6	2.3		
2537040.885	1426173.638	1.8	1.6	2.3		

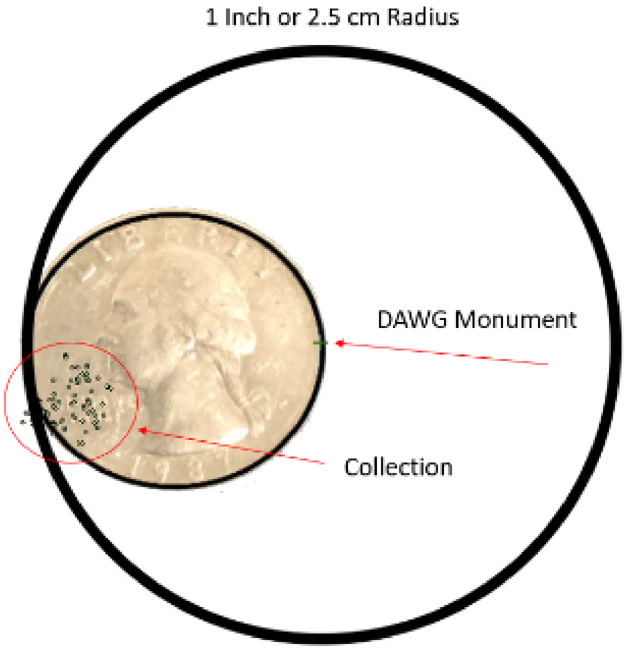




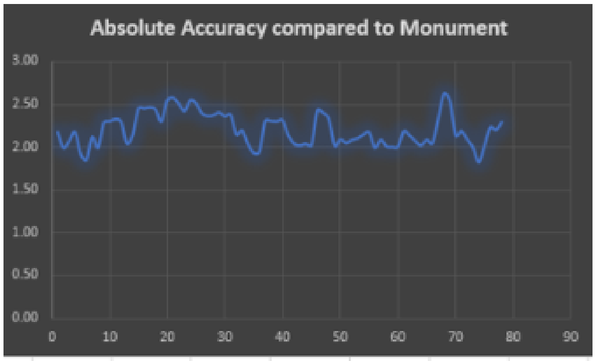
Finally, let's add that final level of detail to determine how it falls in with a reference. We collected this data over a local NGS monument. This monument was last adjusted to the NAD 83 reference datum in June of 2012, almost a decade ago.

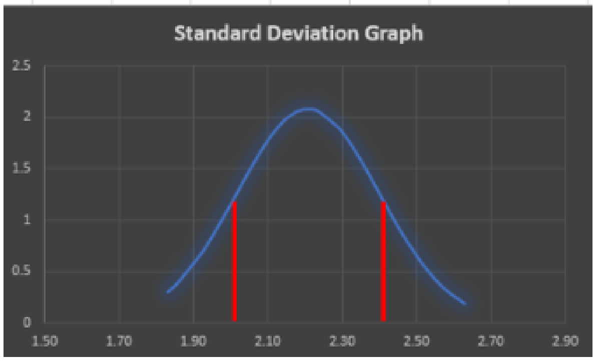
So, as we discussed earlier, our data has moved in relation to that point over the last decade. How much so depends on *where* we are and *when* we collected. Fortunately our monument in NorthEast Georgia is in an area of fairly low tectonic movement. On the right is what the collected data looks like in comparison to the monument. We have inserted a standard US quarter to give a better idea of scale than just a simple scale bar.

As you can see, the precision will remain the same, but our actual "accuracy" in comparison to a "known" reference point will shift a little bit. In our case, our absolute accuracy in comparison to our monument hovered around 2 centimeters (remember 1.6 reported), with an absolute standard deviation of 1.9 millimeters; a precision that actually far exceeds the specification.



So, you can hopefully now see that while a GNSS receiver specification will usually mention "accuracy," they are really talking about precision. The reported value gives a level of precision that each of the points will fall in with other points collected in the same session and in relation to a constantly changing framework. The accuracy that those positions fall in with your location on the earth will be very dependent upon what you are using as a reference, how well and how recently it was established, and most importantly, how you might be translating that to a different reference frame.





X	Y			DeltaX (cm)	DeltaY(cm)	DeltaXY	DeltaXY	Normal		
2537040.89	1426173.66	Absolute X:	2537040.96	-2.17	-0.11	2.18	1.83	0.296858	Average Absolute Error(cm):	2.21
2537040.89	1426173.65	Absolute Y:	1426173.66	-1.99	-0.20	2.00	1.86	0.386323	Standard Deviation(cm):	0.191145
2537040.89	1426173.65			-2.07	-0.22	2.08	1.92	0.6702		
2537040.89	1426173.66		1110867.30	-2.17	-0.12	2.18	1.94	0.759568		2.02
2537040.90	1426173.65		3963214.62	-1.90	-0.31	1.92	1.95	0.828452		2.40
2537040.90	1426173.65			-1.82	-0.38	1.86	2.00	1.143023		
2537040.89	1426173.65			-2.11	-0.22	2.12	2.00	1.147368		
2537040.89	1426173.65			-1.99	-0.22	2.00	2.00	1.154618		
2537040.89	1426173.64			-2.23	-0.51	2.29	2.00	1.156266		
2537040.89	1426173.65			-2.26	-0.44	2.31	2.01	1.196193		
2537040.89	1426173.64			-2.28	-0.50	2.33	2.01	1.229549		
2537040.89	1426173.65			-2.28	-0.33	2.30	2.01	1.247902		
2537040.89	1426173.64			-1.99	-0.49	2.05	2.02	1.297017		
2537040.89	1426173.65			-2.10	-0.46	2.14	2.02	1.313414		
2537040.88	1426173.64			-2.40	-0.50	2.45	2.02	1.315307		
2537040.88	1426173.64			-2.40	-0.51	2.46	2.03	1.323457		
2537040.88	1426173.64			-2.42	-0.50	2.47	2.03	1.34434		
2537040.88	1426173.64			-2.39	-0.51	2.44	2.04	1.421498		
2537040.89	1426173.65			-2.26	-0.44	2.31	2.04	1.438863		
2537040.88	1426173.64			-2.46	-0.66	2.55	2.05	1.450752		
2537040.88	1426173.64			-2.51	-0.61	2.58	2.05	1.460302		
2537040.88	1426173.64			-2.43	-0.63	2.51	2.05	1.488551		
2537040.88	1426173.64			-2.36	-0.59	2.43	2.05	1.497228		
2537040.88	1426173.64			-2.48	-0.61	2.55	2.08	1.639247		
2537040.88	1426173.64			-2.42	-0.70	2.52	2.08	1.648638		
2537040.88	1426173.64			-2.33	-0.61	2.40	2.09	1.711915		
2537040.89	1426173.64			-2.26	-0.70	2.37	2.09	1.724475		
2537040.89	1426173.64			-2.28	-0.68	2.38	2.09	1.726877		