QuickSet® Defense Technologies, LLC

MPT Geo Positioning App Note

1 Introduction

This document is intended to support use of the MPT Geo Positioning (GP) feature and help you to achieve the best system performance possible. The sections below describe the system capabilities and steps that must be taken to achieve that level of system performance when using GP.

1.1 Scope

This note is intended to support the use of the MPT GP features. It is not a reference for GPS usage or capabilities in general.

1.2 Terms and Definitions

Term/Acronym	Definition
FOV	Field Of View
LAT/LON	Latitude and Longitude
MPT	Moog Pan and Tilt – a generic reference to this family of products
RMSE	Root Mean Square Error - a standard measure of agreement between expected and observed results. Lower RMSE indicates better agreement.

1.3 Revision History

Version	Date	Initials	Description
0.1	8/9/21	JD	Initial Draft
0.2		JD	Cosmetic refinements
0.3	12/28/21	JD	Expanded intro section

2 Geo Positioning Usage

2.1 System Capabilities

Under optimum conditions, the MPT is capable of the following GP angular accuracy:

Fixed MPT location/elevation:

- Pan axis: 0.67° RMSE
- Tilt axis: 0.15° RMSE

Live GPS MPT location/elevation:

- Pan axis: 0.85° RMSE
- Tilt axis: 0.69° RMSE

***NOTE**: RMSE = Root Mean Square Error, which is a standard measure of agreement between expected and observed results. It <u>does not</u> define the maximum error that may be observed.*

2.2 Installation

Several factors related to the mounting of the MPT can influence GP performance. They are detailed in the following sections.

2.2.1 Rigid Mounting

The MPT must be firmly mounted to prevent the possibility of any shift in its position or orientation as a result of external forces or reactions to the motion of the MPT itself. Failure to provide a sufficiently rigid mounting will result in increased error in GP results.

2.2.2 Level Mounting

The mounting base of the MPT must be level. Any deviation from horizontal in the mounting base will be directly reflected in GP results.

Deviation from level mounting will impact the tilt accuracy differently depending on the pan angle of the target. For example, if the MPT base is inclined 2° towards due north, targeting error to the north will be above the target, and error to the south will be below the target. This effect will be minimized for targets that are close to due east or west. This pattern of error can be used to detect non-level mounting conditions.

2.3 Configuration

Incorrect configuration settings can also degrade GP performance, as described in the sections below.

2.3.1 MPT Location

Since the calculation of the pan and tilt angles required to view a target are based on the locations and elevations of both the MPT and the target, any error in the MPT location or elevation will degrade GP performance.

Such a location error could be indicated by consistent MPT targeting errors when viewing in one direction, and in the opposite direction, but good performance when viewing perpendicular to this line. For example, if the view is consistently off target to the right when looking east, and consistently off target to the left when looking west, but targeting is good when looking north and south, this suggests an error in the MPT location to the north. See Figure 1 below for an illustration of this situation.

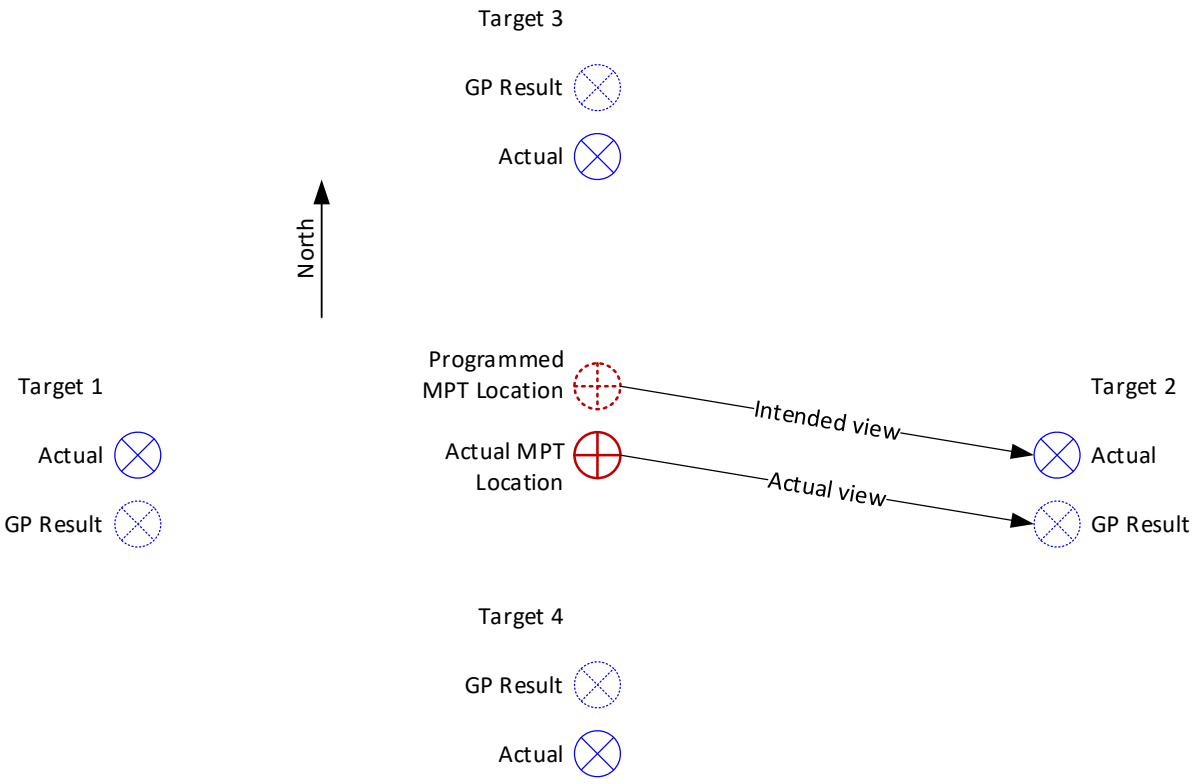

Figure 1 - Effects of an MPT Location Error

An error in the elevation of the MPT will also affect the targeting results, but in the same direction (i.e. too high or too low) regardless of pan angle (assuming the mounting is level, see section 2.2.2). For example if the programmed MPT elevation is too high, GP views will consistently be below target.

Such observations can be used to refine the programmed MPT location and elevation, thereby improving the targeting performance.

2.3.1.1 Live GPS Location

Repeated location readings from a stationary GPS receiver will exhibit variation over time (i.e. "drift"). This variation is commonly limited to within 3 meters of the actual location in any direction. If you're using the live GPS location feature of the MPT, this variation will degrade the performance of GP (see section 2.1).

Because GPS error in elevation is approximately 3 times worse than in LAT/LON, the tilt performance suffers more under these conditions.

To achieve the best performance, it is recommended to use an accurate, fixed MPT location and elevation if possible.

2.3.1.2 Fixed Location

This approach eliminates the influence of GPS drift on GP performance, but it requires that accurate LAT/LON and elevation coordinates be used to get the best performance. Of course this approach is of limited use in mobile applications, unless changes in location are relatively infrequent and the need for maximum accuracy is high.

Accurately determining the coordinates of a location is possible with common GPS devices (e.g. hand-held receivers, smartphones) if a sufficient number of readings taken over a sufficient period of time are considered.

GPS drift is a fairly slow phenomenon, requiring minutes, not seconds, for significant changes in calculated location to occur. Because of this, 20 readings acquired in 20 seconds will not yield as accurate an average location as would 20 readings acquired evenly throughout 60 minutes. This is especially true of elevation data because of its poorer accuracy.

The best way to determine the fixed location of an MPT installation is to collect GPS LAT/LON and elevation readings from a receiver mounted as close to the center of the MPT as possible[1] every few minutes until the data converges. This can be a judgement call, but some indications of convergence include:

- Subset averages agree closely with the overall average: e.g. the average of the first half of the readings matches the average of the second half, and both match the average of all the data.
- Plots of new readings consistently fall within the range defined by previous readings (see Figure 2 below)

***NOTE**: When collecting such data, it is important that the latitude, longitude, and elevation recorded come from the same GPS calculation. For example, the location / elevation data reported by GPS receivers is commonly updated once per second. Capturing LAT/LON and elevation from the same update (e.g. by capturing a screen shot) provides better data that recording LAT, LON and elevation one-at-a-time as the data changes.*

It is illuminating to plot such data and its average. An example of such a plot is shown in Figure 2 below. The effect of drift, and of averaging a set of readings can be clearly seen.

[1] Any distance between the MPT and the receiver will add error to the targeting results, see section 2.3.1

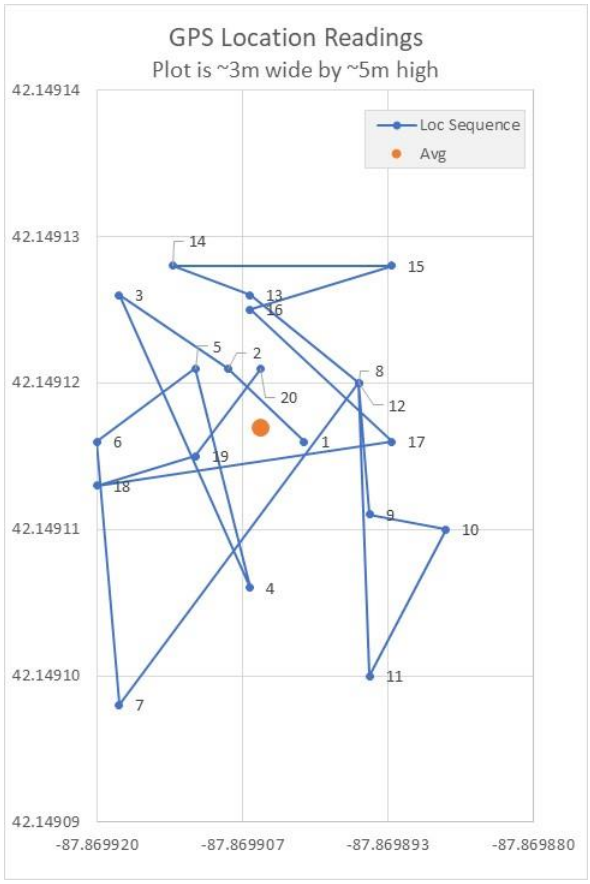

Figure 2 - GPS Location Readings

In Figure 2 above, 20 GPS LAT/LON readings are shown, identified in order of acquisition, and connected by lines indicating the apparent path taken by the stationary receiver. Readings were taken approximately every 2 minutes. The average of the readings is shown as an orange circle. A similar plot of successive elevation readings can also be created.

This plot suggests that the acquired data set is likely approaching a fairly accurate average location because the readings appear to be more or less randomly distributed around the average. If for example, the readings all fell on a single line or curve, confidence that the data set is sufficient would be lower.

2.3.2 MPT True North Offset

The MPT must be configured with the pan angle corresponding to true north in order to convert geographical directions into pan angles. Any error in this parameter will be apparent as a consistent targeting error in the same direction.

For example, if the GP view results are always off target to the left or to the right regardless of pan angle[2], refining the true north setting can minimize this error. Consistent targeting error to the left means the true north offset should be increased. Likewise, targeting error always to the right suggests a decrease in the true north offset is necessary.

2.4 Inherent Errors

Certain errors and uncertainties are inherent in the GP process and cannot be corrected by the MPT. Some prominent sources of error are described in the sections below.

2.4.1 Target Location Errors

The accuracy of GP targeting is limited by the accuracy of the target locations the MPT is commanded to view.

If target coordinates are obtained from a single GPS reading, the errors mentioned in section 2.3.1.1 apply, and the MPT can do no better than that in viewing a specified target.

Coordinates obtained from Google Maps or similar sources are commonly reported to 6 decimal places, but their accuracy is almost certainly not as good as that precision implies. Data obtained from such sources cannot be considered any more accurate than that from a hand-held GPS receiver, and in some cases (e.g. remote areas where such mapping data is less scrutinized) may be substantially worse.

For repeatedly viewed targets, observed targeting error patterns can be used to refine the target coordinates.

In the case of transient targets, no such historical refinement is possible. Therefore, it may be necessary to adjust the initial FOV so that the resulting view is very likely to include desired target, and then refine the pan, tilt, and FOV manually to achieve the desired view.

2.4.2 Imprecise Target Location Entry

At the equator, 1 meter corresponds to about 9×10^{-6} degrees (9 millionths of a degree) of latitude or longitude. To put it another way, specifying LAT/LON accurate to 5 decimal places will get you to within about 1 meter of the desired spot. This leads to the following approximate relationship between coordinate precision and location accuracy limits:

# Accurate Decimal Places	Approximate Location Accuracy
5	± 1 m
4	± 10 m
3	± 100 m
2	± 1000 m

[2] This is as opposed to error that varies with pan angle, see section 2.3.1.

This relationship is important to keep in mind when entering coordinates to be viewed. Especially for narrow FOV systems, more precise target coordinates are necessary to achieve the best GP performance.