

GPS Device Comparison for Accident Reconstruction

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ABSTRACT

The GPS (Global Positioning System) is a navigational tool available to the public, comprising in part a network of satellites in orbit broadcasting signals to GPS receivers on earth. Due in large part to the very accurate clocks in the system, a GPS receiver that receives a number of these signals simultaneously can then establish its location on earth. Some GPS receiver models have the capability to record a history of the latitude and longitude co-ordinates at known times, and these may later be downloaded and viewed on a computer using applicable software. Effectively, this provides the equivalent of a bread crumb trail of the path taken by the receiver, although the frequency of the data points can vary substantially from one model to another, and it may not be adjustable by the user. By plotting the information on a map, the trail can be viewed and the position-time history of the vehicle may become evident. The ability to obtain data from a GPS device that was present in a vehicle during a crash could therefore provide data that would interest an investigator. This paper examines the accuracy of the trail history recorded on several GPS devices of different brands and price levels, for the purpose of determining the accuracy to a known baseline trail established with an engineering-grade GPS data logging unit. Units available for approximately \$100 up to one valued at over \$1000 were used, with the latter unit designed for aviation use in addition to automotive use. Of particular interest was whether or not the recorded trail data could show subtle driver actions such as complete, or even partial, lane changes. For this research, the test vehicle was driven on a chosen course involving accelerating from a stop to highway speeds, steady cruising, and slowing to a stop. Various steering actions including lane changes were used. The resulting test data was compared. Subsequent testing compared the results from two units of the same brand and model.

CITATION: Bortolin, R., Hrycay, J. and Golden, J., "GPS Device Comparison for Accident Reconstruction," *SAE Int. J. Passeng. Cars - Electron. Electr. Syst.* 5(1):2012, doi:10.4271/2012-01-0997.

INTRODUCTION

If an accident-involved vehicle had a functioning hand-held GPS device on board capable of recording data, and if the data could subsequently be retrieved, it might be of considerable interest in an accident investigation. The popularity of affordable consumer GPS models is likely to result in increasing availability of GPS data from accident-involved vehicles. Existing research on GPS devices has been done, in particular with respect to their speed accuracy (Reust [1,2,3,4]). This paper strives to elaborate on existing testing, and to consider positional accuracy and the ability to show the traveled path. The testing included receivers from different manufacturers and at different price ranges.

When GPS coordinates are coupled with time, the data effectively is a position-time history. Other information can thus be determined, such as the speed, heading or distance between two consecutive points. In many investigations, a determination of the pre-impact speed would be of particular importance. In others, it might be useful to know the lane of travel of a vehicle, for example to better understand what evasive action a driver did or did not take. This paper explores both speed and position aspects. This was done by comparing the bread crumb trails to the baseline trail recorded by an engineering-grade data logging system.

METHODOLOGY AND TEST RESULTS

TEST EQUIPMENT

Testing was performed on westbound I-70 near Kansas City, Kansas on 1 December 2010. The vehicle used was a 2005 Freightliner tractor. The baseline paths were established with a Racelogic V-BOX III GPS-based data-collection unit with a reported accuracy of 0.1 km/h averaged over 4 samples and a positional accuracy of 3 m 95% CEP, which indicates a co-ordinate will fall within a 3 m diameter circle of the stated position 95% of the time. V-BOX GPS units have been used in past research to establish position-time baselines of motor vehicles in various testing (Reust [1,2,3,4], Ruth et al [5], Bortolin et al [6]). In addition to the V-BOX, four GPS receivers were used in the I-70 testing, as noted below:

Garmin nuvi 265, S/N: 1RD092880, Map Version: CN North America NT 2010.10, Retail price: \$100 USD

Garmin Aera 510, S/N: 1QR001494, Map Versions: Worldwide Aviation Basemap v 2.00 (also: CN North America NT 2010.20), Retail price: \$1099 USD

Magellan eXplorist 210 version 3.1.78, S/N: 0112570014476, Map Version: 3.1.78, Retail price: \$180 USD

TomTom One, S/N: PB4218F07004, Map Version: USA_and_Canada v715.1712, Retail price: \$100 USD

Garmin indicates that their "GPS receivers are accurate to within 15 meters (49 feet) 95% of the time with a clear view of the sky. Generally, users will see accuracy within 5 to 10 meters (16 to 33 feet) under normal conditions." (Garmin [7]) Garmin also indicates that "GPS receivers with WAAS (Wide Area Augmentation System) capability can improve accuracy to less than 3 meters (10 feet) on average. Certain Garmin GPS devices are equipped with this system." (Garmin [8]) The nuvi 265 model does not have WAAS, therefore the former stated accuracy would apply to that model. The Aera 510 model does have WAAS capability therefore has the improved stated accuracy. The Magellan eXplorist 210 is equipped with WAAS, and when it is active the standard positional accuracy of 7 m (23 feet) improves to 3 m (10 feet) 95 % 2D RMS, indicating the percentage of points that are expected to fall within the stated distance (Magellan [9]). The eXplorist 210 display can indicate when WAAS is active, although that status is not reported in the recorded trail data. TomTom does not apparently publish the positional accuracy of the One unit. The reference manual for the TomTom One offers a disclaimer that the GPS system is operated and controlled by the United States of America government which is responsible for its availability and accuracy. (TomTom [10]).

METHODOLOGY

The V-BOX antenna was initially placed along the centerline of the tractor under the glass at the base of the windshield in the first six test runs, in order to be close to the hand-held units inside the tractor. For the last three runs, the antenna was moved forward to the front of the hood along the centerline of the vehicle. This resulted in the number of satellites being received by it increasing to between 7 to 9, where in the earlier runs it was as low as 4 satellites. As such only the latter three runs (Run 7 to 9) were used in the analysis.

For all runs, the hand-held GPS receivers were mounted together on a small plastic board which was held by a passenger seated in the right seat. As such, the receivers were approximately 60 cm to the right of the vehicle's centerline.

Each test run began from a common stopped position on the westbound right shoulder, where the tractor's right wheels were approximately at the right edge of the shoulder. The tractor then accelerated up to normal highway speed merging left into the westbound travel lanes. Three scenarios were conducted. In Run 7, the tractor completed a full lane change from the right lane to the left lane, before returning to the right lane. It then slowed to a stop in the right shoulder. In Run 8, it completed only a partial lane change from right to left, where it momentarily straddled the lane lines between the two lanes before returning to the right lane. It then continued on to the next right-hand exit of the highway. In Run 9, no lane change was performed and the tractor remained in the right lane as a control to the other runs. It then slowed to a stop in the right shoulder. The data from the devices was downloaded from the runs. A particular aspect being explored was whether or not the GPS trails on the devices would be able to show the differences between no lane change and a partial or full lane change.

Subsequent testing that focused on comparing two nearly identical Garmin nuvi models was performed between Windsor, Ontario and Chatham, Ontario on 31 March 2011.

The Garmin devices were downloaded with Garmin MapSource version 6.16.3 software. The Magellan eXplorist 210 was downloaded with Magellan VantagePoint file version 1.0.0.0 software. It was not possible to record and download trail information from the TomTom One, however for comparative purposes a video camera was used to record the latitude, longitude and speed shown on the display. Space allowed both Garmin units and the eXplorist unit to be included in the view of the camera, but vibration and glare during driving prevented them from always being clearly visible. However, their trails were able to be downloaded.

The data frequency on the V-BOX was 100 Hz. The Garmin Aera 510 was set to aviation mode in order to record data at the highest setting of 1 Hz. The frequency of data collection on the other models could not be set by the user, and varied considerably. For example, the Magellan eXplorist 210 recorded three points in Run 7 over a period of over four minutes.

The downloaded data included the latitude and longitude, so by plotting the co-ordinates on a map and connecting the points with different lines, the trails could be visually compared. Google Earth was used as the primary mapping software to do this. The V-BOX co-ordinates established the baseline to which the other units could be compared.

To further compare trails to the baseline, the differences between the trails to the baseline at various points were determined and are shown in table form. The distance represents approximately the shortest distance between two nearby points.

DISCUSSION

The V-BOX trails for Runs 7 to 9 show the starting location in the right shoulder of the highway, followed by the gradual transition out onto the roadway. The trails show where the tractor then moved right into the shoulder where it came to a stop, for the two runs where that occurred. The approximate location of the start and stop locations shown in the V-BOX trails was fairly consistent with the centerline of the vehicle based on the relative location of the vehicle on the shoulder. In other words, the V-BOX co-ordinates for the start and end positions, once plotted on Google Earth, were represented to be on the shoulder at approximately the expected locations. Then, the remaining V-BOX trail data was evaluated against the map. The data were found to show both full and partial lane changes consistent with the test scenario and our general observations from within the vehicle.

The same method was applied to compare the trails from the hand-held units. Some of the results showed the tractor's starting positions as being in the grass well north of the shoulder or on the westbound roadway in the right lane, when it was actually in the right shoulder. In other instances, when the tractor was travelling in the right lane the hand-held device trail indicated it was in the left lane. These observations were made from viewing the results on the map, however it is important to note that the co-ordinates themselves define the trail. An individual trail could be compared to the baseline trail by looking at the data on a point by point basis. The distance between two nearby points was calculated and shown for the various runs in the noted tables.

No defects with the hand-held devices were noted, and no defects or problems should be inferred from this testing. However, when compared to the V-BOX baselines, it can be seen that they did not show their location as accurately. Figure 1 shows a close-up plan view of westbound I-70 near the start of Run 7. It was created based on a view from Google Earth. The travel lanes were approximately 3.6 m wide and the right shoulder was approximately 3.0 m wide; typical of a major roadway. Note the baseline V-BOX path exiting the shoulder and entering the right westbound lane. The Garmin Aera 510 was the closest of the other GPS devices, yet it was biased to the south. It showed the path beginning in the right lane rather than the shoulder. The Magellan eXplorist 210 and the Garmin nuvi 265 exhibited more variation. The largest difference to the baseline was noted on the TomTom One, which based on the video the co-ordinates located it across the roadway and in the eastbound travel lanes. The markers on the lines indicate the locations of the data points.

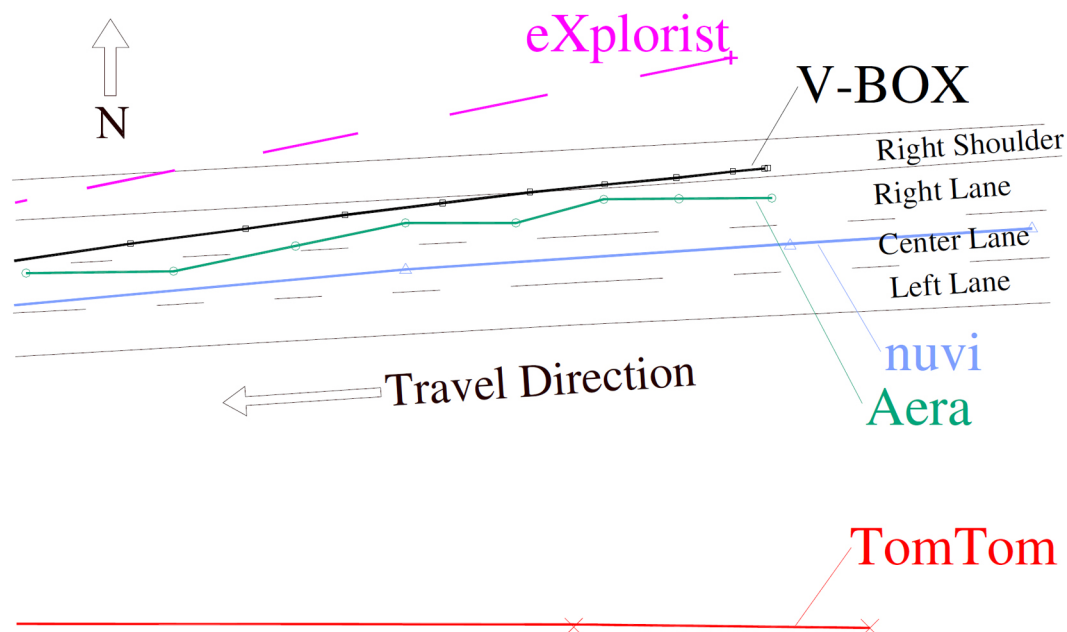


Figure 1. Run 7

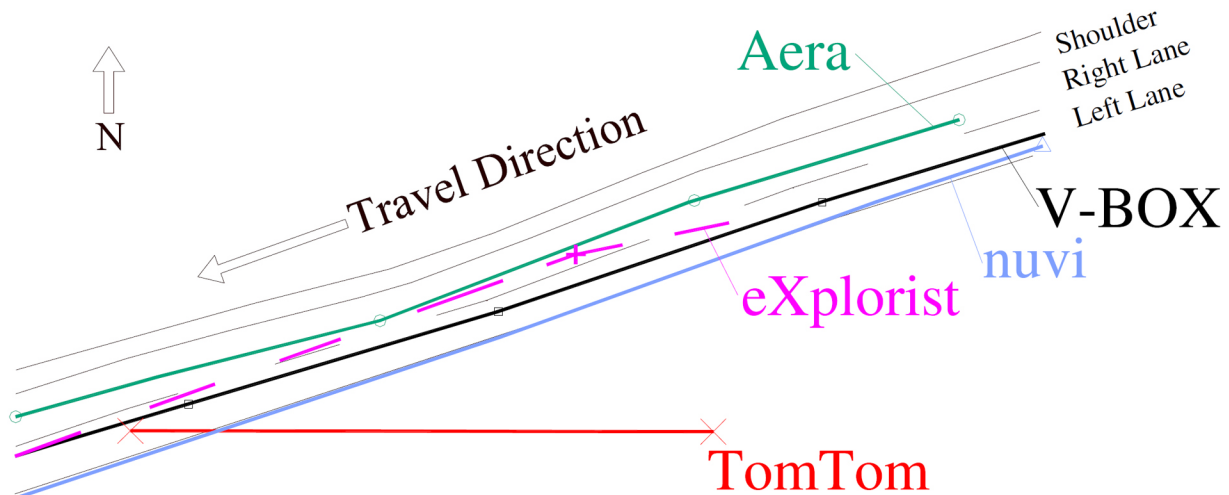


Figure 2. Run 7

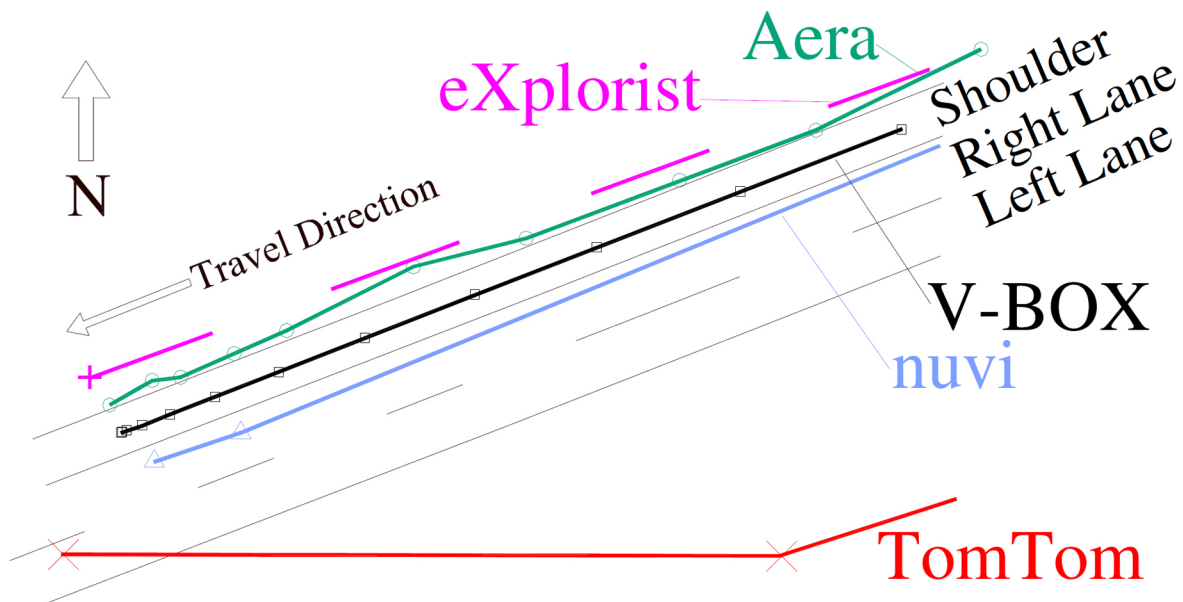


Figure 3. Run 7

Figure 2 is from Run 7 after traveling further west where there were two westbound lanes, as the right lane and center lane had combined into a single lane. At that time, the vehicle was fully in the left lane but was beginning to slowly move right toward the right lane. None of the GPS units showed this tendency, as shown in the figure. This area is an overpass over an underlying roadway. There is some optical distortion making the lanes appear to slightly narrow, however the lines as shown in the figure follow the contours of the lanes.

Figure 3 shows the end of Run 7, where the tractor had come to a stop centered in the right shoulder as shown by the V-BOX data. The other units exhibited various amounts of error to that baseline.

Figure 4 shows the partial lane change of Run 8. The V-BOX path shows the tractor's centerline moving left to the point of nearly straddling the lane lines between the left and right through lanes, before moving to the right. For clarity, the left through lane is hatched. None of the GPS units were able to show this partial lane change.

Table 1 is a view of Run 8 data from the Garmin nuvi 265, using the MapSource software. The GPS co-ordinates and the clock times allow other parameters such as Leg Time, Leg Distance and Leg Speed to be determined. The Leg Speed is, in effect, an average speed between points and therefore not necessarily a true indication of the actual speed of the vehicle at that instant. All things being equal, a higher recording frequency would result in shorter Leg Times and in such case the Leg Speed would more closely represent the actual speed of the vehicle at that instant.

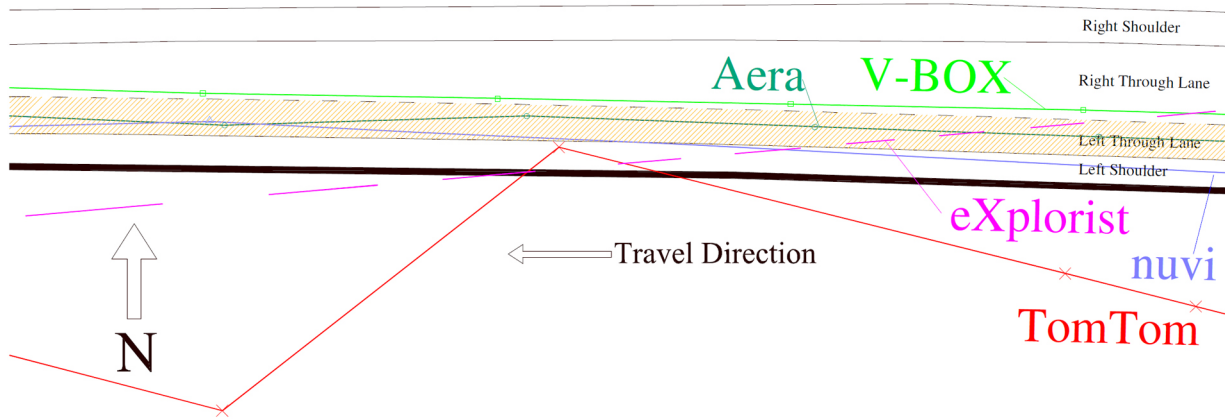


Figure 4. Run 8

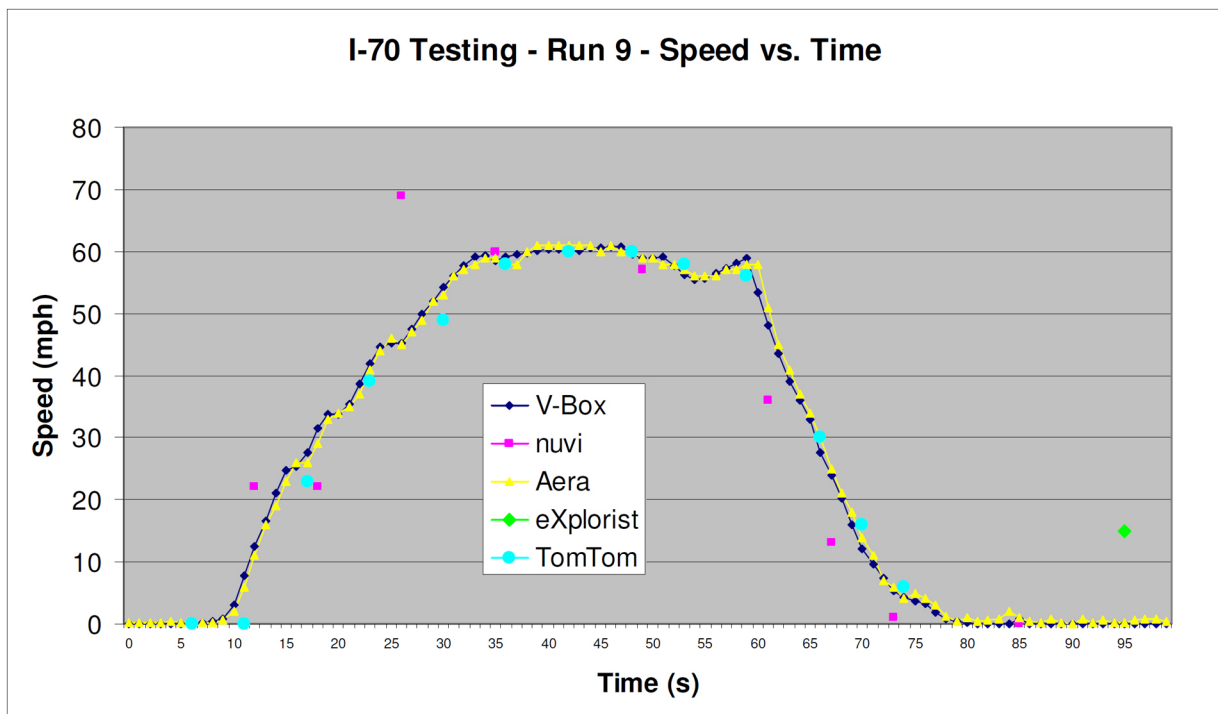


Figure 5A. Speed vs. Time - Run 9

Figure 5A is a graph of Speed vs. Time for Run 9, with the data synchronized for visual purposes to an approximately equal time scale. The Garmin nuvi 265 and Aera 510 speeds shown are the “Leg Speed”. The TomTom One data is taken from the video, and is included for comparative purposes. The Magellan eXplorist 210 unit had only one data point during this period of time. In Run 9, one of the Garmin nuvi 265 Leg Speed readings was 69 mph (111 km/h), which was actually higher than the speed of the tractor at any time in the run.

Figures 6A and 6B (close-up) show Run 8. Note that the Garmin nuvi 265 data indicates a Leg Speed of 0 mph for several seconds before increasing to 319 mph (514 km/h). In this instance, the tractor was turning right off the highway at the next exit. The unit recorded six identical co-ordinates in a ten second period, then ‘jumped’ to the next point in one second resulting in a large distance between the co-ordinates and therefore a large spike in speed. Based on the co-ordinates, the distance of the jump was 143 meters. As it was interpreted as occurring in one second, the resulting speed was 514 km/h. As such, when viewing Leg Speed data, it is important to understand it may differ from the actual speed in particular if the Leg Time is lengthy.