Attachment A

Evidence relating to the integrity of the GPS data, concerning the speed and passage of Frankston 251 and Frankston 615

1. The police members involved in the pursuit initially refuted the integrity of the Motorola GPS data, and that data and the integrity of the Motorola GPS system was fully examined during the inquest.

2. Issues that arose regarding the data included the following:

   a. The margin for error in plotting GPS location / coordinates in 2 dimensions (i.e. on a map), and the sky plot tool (dilution of precision).

   b. The location of the GPS antenna in the vehicle and the effect on perimeter of and margin for error;

   c. The margin for error for measuring instantaneous velocity, including the manner in which intentions velocity is calculated;

   d. The integrity of data transfer between the Motorola Data Terminal and the Motorola databank (and time delay, if any); UTC and GMT time and the effect, if any, this has on the integrity of the data;

   e. The verification by the police members of the GPS plots by reference to landmarks mentioned on the D24 tape;

   f. The accuracy of GPS plots on the map.

1. **The margin for error in plotting GPS location in 2 dimensions (i.e. on a map);**

   a. Mr Phil Sidebottom, engineer at Motorola, gave evidence that the MDT provides horizontal GPS coordinate accuracy to within 6 metres for 50% of the time, and less than 9 metres for 90% of the time. Those were the levels of accuracy required under the contract between Motorola and the Emergency Services Telecommunications Authority.

   b. Mr Sidebottom also gave evidence about the skyplot tool, which is a tool provided by Trimble, the manufacturer of the GPS card that sits within the Motorola Data Terminal. The sky plot tool is described at pages 5 – 7 of Mr Sidebottom's presentation materials (exhibit 23C). The sky plot provides a 'bird's eye' view of the sky above the GPS

antenna (or a designated position in that area on the ground) to illustrate the presence and location of GPS satellite coverage.

c. The GPS data becomes more accurate as the number of satellites available increases and as the distance between those satellites, within the observable sky, increases. This is based on principles of geometry triangulation.

d. **Mr Sidebottom summarised the dilution of precision principal and the sky plot as follows, concluding that there was very good satellite visibility with a resultant low dilution of precision which gives a high confidence in the GPS data as being within the 6 metre margin for error specified for at least 50% of the time:**

> *[re skyplot] - It's actually a combination, Your Honour, of the number of satellites which are visible, which are obviously very important but also the geometry, if you like, which is created by those satellites. Because it is a well understood fact that we are using triangulation in this technology, with distances measured from each of a number of satellites - up to 10 satellites. If we have a situation where all of those satellites are very closely clumped together, the opportunity for reduction of error through triangulation is much reduced so we find we get a far more reliable result if the satellites are not only visible - that is above the horizon, but they are also separated, which is what we were looking at on the previous sky plot.*[1]
>
> *the dilution of precision measurement, is normally considered to be in the range of excellent if it is below five, and we see here that we are, you know, even taking*[2]

e. The Trimble Planning Tool on page 6 of exhibit 23C (Sidebottom's report) shows that the Dilution of Precision was well below 5 at all material times; it was below 2.6 for most of the time.

f. Inspector Ross Oberin gave evidence that the GPS antenna would have been at the rear position parcel shelf of the TMU Commodore.[3]

g. Canyoning is the effect of buildings and other such objects obstructing the line of site between the GPS antenna and the GPS satellites. Mr

---

[1] See transcript at page 641.
[2] See transcript at page 645.
[3] See transcript at page 426.

Sidebottom gave the following evidence about the effect of canyoning in this case:

> *I saw no evidence for any kind of structure or building which could have caused that kind of canyoning effect.* [4]

2. **Margin for error for measuring instantaneous velocity. The manner in which intentions velocity is measured, and in particular, whether the system calculates instantaneous velocity as a function of GPS plots over time (distance over time);**

   a. The manner in which instantaneous velocity is derived by the (Motorola Data Terminal) MDT became a contentious issue in the inquest, namely because the MDT recorded Frankston 615's instantaneous velocity as high as 177 km/h.

   b. Phil Sidebottom initially gave evidence that instantaneous velocity was measured by the MDT system continuously calculating distance over time – and that it did so at a continuous and faster rate, internally within the system, than the rate at which the system was reporting speeds. In pursuit mode, the MDT would report speeds and location every 100 metres, or every 15 seconds, but not more frequently than every 3 seconds.

   c. At 120 km/h the vehicle is travelling at 33 metres per second, and hence will be covering 100 metres in 3 seconds. Hence at 120 km/h per hour, the vehicle is reporting its speed every 3 seconds and is covering 100 metres within that time interval.

   d. At speeds beyond 120 km/h, the vehicle is covering more than 100 metres in each 3 second interval.

   e. Mr Sidebottom initially gave evidence that the instantaneous velocity as contained within the 'Motorola GPS data – Oberin's spread sheets'[5], is calculated by the MDT by calculating distance over time in a continuous manner. This was later corrected and the inquest heard that instantaneous velocity is in fact calculated by the MDT using the Doppler Effect.

   f. Counsel for the members challenged the reliability of the instantaneous velocity measurement as 'within 0.06m/sec' if it was in fact measured as distance over time. After all, if there is up to a 6 metre margin for error (i.e. 3 metres in any direction) in plotting location, and if speed is calculated as distance over time, then that margin for error, it was submitted by counsel for the members in the pursuit vehicles, would translate into the velocity measurements.

---

[4] *See transcript at page 693.*

[5] Exhibit 16A – tables of GPS data

g. It was clarified later in the inquest that the MDT calculates instantaneous velocity not as a function of distance over time, but rather, using the 'Doppler Effect'.

h. At paragraphs 6 – 7 of his statement (exhibit 38a), Dr Peter Loomis of Trimble Navigation, the manufacturer of the GPS card that sits within the MDT, explains how the Doppler effect is used to calculate instantaneous speed.

i. Dr Loomis stated that:

> *[Dopplers] is in simple terms the speed at which each satellite is approaching the receiver (positive or negative). The Doppler measurement is measured using a different technology (carrier tracking) that is accurate to about 3cm / second. By knowing the orbital speed of the satellite, and measuring the speeds at which they are approaching the receiver, the velocity of the receiver can be measured quite accurately.*[6]

j. Once it was confirmed that the instantaneous speeds were calculated using the Doppler effect, counsel for the members no longer challenged the validity of those recorded instantaneous speeds, having openly been guided in the background by a Mr Gerard Cusick, who had been described as a GPS expert. (Mr Cusick was not called to give evidence and his qualifications were therefore not confirmed).

k. The members conceded that the Doppler Effect is a very accurate measure of determining instantaneous speed. Mr Gipp, counsel for the members in the pursuit vehicles, said:

> *Now that it is confirmed that the Doppler effect is used, as opposed to GPS plotting points, we concede that the speeds stipulated in the spreadsheets as instantaneous speeds are accurate. I haven't been able to make that concession until this point, Your Honour, because all of the research and advice we'd received about calculation of speed on average speeds between two GPS plotting points is subject to error, and that's the reason I took the tack that I did last week in attacking the evidence of Mr Sidebottom in an attempt to reduce what was alleged to be the speed down to what, based on GPS plotting points, might have been a lesser speed.* [7]
>
> *This is in the face of instructions that I have, Your Honour, and the members will explain this today in their evidence, is that at no time do they believe they reached the speeds as alleged in the GPS data. In particular, 615 at one point reaching a speed, instantaneous*

---

[6] Statement of Peter Loomis, exhibit 38a at paragraph 7.
[7] See transcript at page 963.

speed, of 177 kilometres per hour. In the face of what is now conceded to be accurate instantaneous speeds the members must reflect on their recollections of events as to whether there was a possibility that they reached such a speed, but were not aware of it at the particular time.[8]

l. The science and mathematics behind how the Doppler Effect is used to calculate instantaneous speed was not explored in depth in this inquest. This was because it was readily accepted by all parties, upon confirmation by Trimble and Motorola that the Doppler Effect was indeed the technology used to calculate instantaneous speed, that those speeds were accurate and reliable.

m. The members then gave their evidence, conceding the speeds recorded by the MDTs.

n. Of note regarding the accuracy of the velocity (as distinct from location coordinates), is that at paragraph 15 of his report, Dr Loomis says that environmental conditions such as unusual ionosphere conditions and to a lesser extent troposphere conditions that can cause positional error of a few metres on horizontal accuracy, have little effect on velocity.[9]

3. Integrity of data transfer between the Motorola Data Terminal (in the vehicle) and the Motorola databank (and time delay);

a. The inquest heard that the MDT system has an inbuilt 'checksum' feature to ensure the integrity of the data flowing from the MDT to the Motorola database.

b. Before a piece of data is transmitted from the Motorola Data Terminal to the Motorola Message Switch and transaction database, a 'checksum' is applied, which is a random number applied by algorithm.

c. Mr Oberin gave evidence as follows:

> THE *CORONER: How does this check sum work? What does it do? What does it interrupt?---*
> Oberin - *Sir, my understanding is that the data stream up to the check sum point has a hashing algorithm applied to it.*
>
> *Hashing algorithm, it's a mathematical formula applied to it and basically the hash applies at the start or the creation of the string and the result of that hashing formula is a number, X a decimal number. The string is then transmitted from the vehicle and ultimately stored in the transaction database and if the hashing*

---

[8] Ibid.
[9] See Exhibit 38a, paragraph 15.

formula is still intact at the end of that string, then it demonstrates that the creation of the data transmission through the network and through the services and the document storage into the archival system is still intact so the integrity of the data string is intact. That's my understanding, sir.[10]

Each point in particular is of itself correct if there's a checksum. Your Honour, if hypothetically again it looked like it was dropping every second polling point, it wouldn't invalidate the data string but it would make reliance on its alignment with the road a little more problematic to the extent that in an extreme case if we had a polling point and then there was no polling points for 30 or 40 seconds and then there was another polling point and the interim ones had been dropped, that does not allow me to form any firm view about the course of the vehicle on that particular occasion because the data as to where the vehicle could have been has been lost so I've only got a start and a finish but where there's an incident drop in a stream of polling points it doesn't materially affect the confidence level of the movement of the car, sir.[11]

d. Mr Sidebottom offered the following further explanation about the use of the checksum.

In an environment like this, Your Honour, the radio network, which is the base stations and the radios in the vehicles, they operate in a relatively hostile environment from a radio point of view. And by that I mean that the environment is always subject to interference from numerous different sources, you know, man-made and natural, which can affect radio transmissions at any time. And so it's important that when you are transmitting information data over a network like that, you provide the checks and balances which this check sum happens to be, to allow you to determine, at the reception point, if any of your transmissions have been received incorrectly or corrupted in passage through the network. And then, with the checks satisfied at the receiving end, you know that you have made it successfully and securely through the radio network and therefore the data will be valid.[12]

---

[10] See transcript at page 545.
[11] See transcript at page 548.
[12] See transcript at page 625.

4. **Integrity of data transfer between the Motorola Data Terminal and the Motorola databank (and time delay); UTC and GMT time and the effect, if any, this has on the integrity of the data;**

a. Having conceded that the recorded instantaneous speeds were accurate as measures of speed travelled, the members sought to investigate the accuracy of the time stamps applied to those reported velocities, and to effectively explore whether those speeds were travelled as at the times they were recorded as having been travelled, or at some other time. This involved consideration of:

i. Whether there is any time delay in the transmission of the message between the MDT and the Motorola Message switch;

ii. Whether the time stamp is applied at the MDT or at the point of reception at the Message Switch?

iii. Whether the GPS satellites, the Motorola Data network, and the ESTA systems are all speaking the same 'time language' – and if so, whether that time language is UTC time or GPS time.

b. **Message delay / time lag**

i. Dr Peter Van Wyck Loomis of Trimble Navigation, the manufacturer of the GPS card within the MDT, was asked to address these issues. His statement is at exhibit 38a.

ii. Regarding time lag in transmission of data, Dr Loomis provided as follows:

> *The Lassen GPS module provides a position and velocity every second. The timetag on the data is accurate, but the data is not available for maybe 0.4 seconds. The velocity on the Lassen SkII is the average velocity during the 0.2 second before the time tag.* [13]

c. **Time language – UTC time or GPS time? Are the systems all in sync?**

d. In Andrew Richards' second statement of 16 September 2011 he stated that the Emergency Services Telecommunications Authority (ESTA) and its 'talking clock' use 'Corrected GPS time', which is another term for UTC time.[14] Andrew Richards amended his statement to change the reference to 'corrected GPS time' to become a reference to UTC time – they are one and the same.[15]

---

[13] Statement of Dr Loomis, exhibit 38a, paragraph 13.
[14] Exhibit 26a
[15] Transcript, page 1682, line 20 & transcript page 1683, line 9.

e. Grahame Stanley from Motorola gave evidence and provided a statement (exhibit 40) in which he stated that while the Motorola systems use GPS and UTC time, **the data that is extracted is in UTC time**. He stated as follows at paragraph 20 of his statement:

> *In order to be able to interpret the GPS time embedded in the vehicle*
> *location/velocity poll message, the information is extracted from the Transaction Database and inputted into a spread sheet which converts GPS time embedded into the vehicle location/velocity poll message into UTC (local time).* [16]

f. Mr Stanley stated further in statement of 16 September 2011 as follows:

> *The GPS time contained in the GPS vehicle location/velocity poll message is never altered and there is no scope for any time lag or drift between what is inputted and what is outputted from the MDT. The time embedded in the message is inserted by the Trimble Lassen SKII device.*
>
> *The reason for the differential between GPS and UTC is set out above. This does not impact on the accuracy or reliability of the time recorded in the GPS vehicle location/velocity poll.*

g. So in the end it was clarified that the references to time in Oberin's spread sheets[17] (the Motorola GPS data) is in UTC time, and ESTA's systems and their talking clock are also in UTC time - hence the GPS data and the police radio sequence (D24) are in sync. To use the phrase of counsel for the Chief Commissioner of Police, all relevant systems are 'marching to the same beat'.

h. It was also accepted by all parties that the time stamp applied to each piece of data is accurate, or that any margin for error is sufficiently small as to be rendered negligible.[18]

5. Verification by the police members of the GPS plots by reference to landmarks mentioned on the D24 tape.

g. There is a strong correlation between the information recorded in the D24 transcript[19] and the Motorola GPS data. Taking into account margins for

---

[16] Paragraph 20, statement of Grahame Stanley, exhibit 40.
[17] Exhibit 16A – tables of GPS data
[18] Dr Loomis stated that "*the velocity on the Lassen SkII is the average velocity during the 0.2 second before the time tag*". That time lag associated with averaging the velocity across the 0.2 seconds before the time tag is applied is sufficiently negligible such that the accuracy of the time tag was accepted by all parties.
[19] See Exhibit 19B

delay associated with the happening of an event, the observation of that event by the pursuing member, and the verbal transmission of that event by radio (including transmission time), the D24 transcript appears to strongly reflect the Motorola GPS data and serves a working verification of its accuracy. Below are a number of examples of strong correlation between the Motorola GPS data and that which was recorded on the D24.

h. Example 1:

i. According to the D24 transcript[20], at 00.00.36 Frankston 251 transmits "just going through Seaford Road on the green".

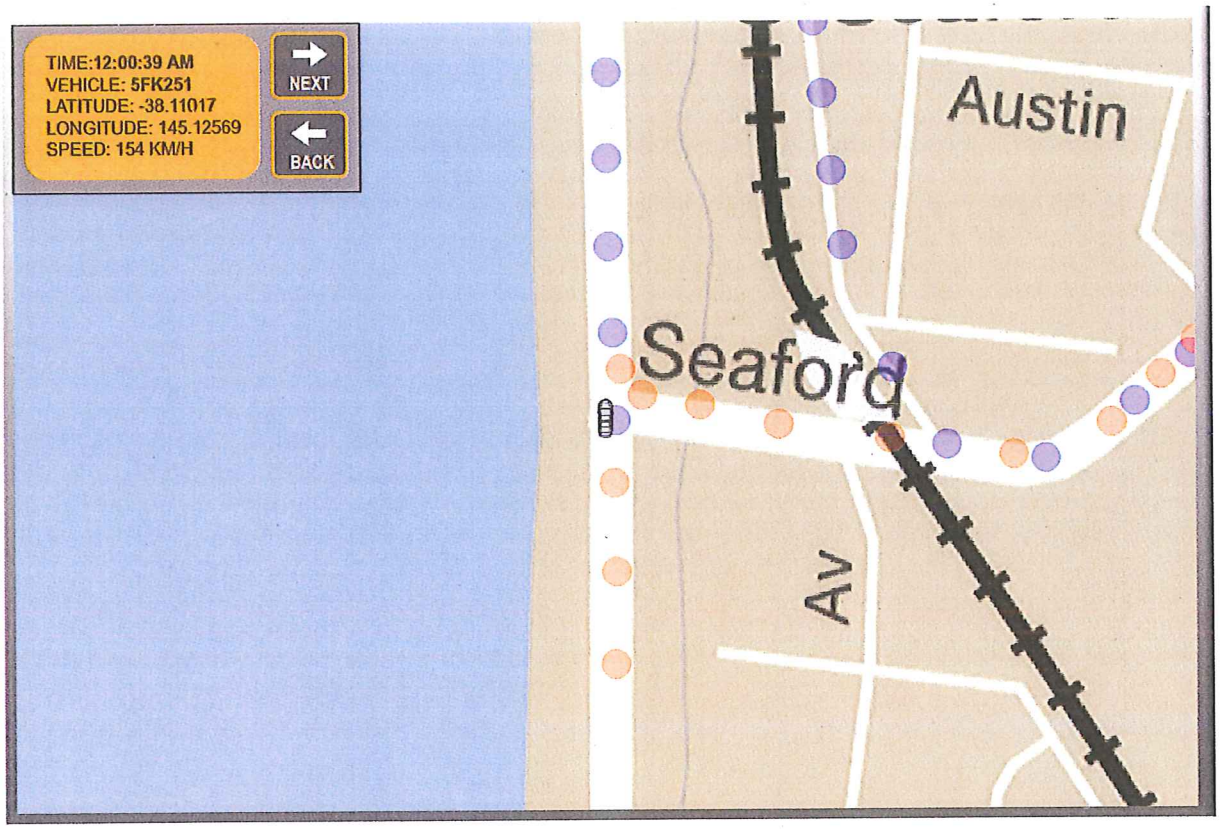
ii. The GPS data and the Animation of Pursuit[21] (which is based on the GPS data), shows that 00.00.39 Frankston 251 is entering the intersection of Seaford Road, and at 0.00.42 Frankston 251 has passed the intersection of Seaford Road travelling at approximately 153 km/h.

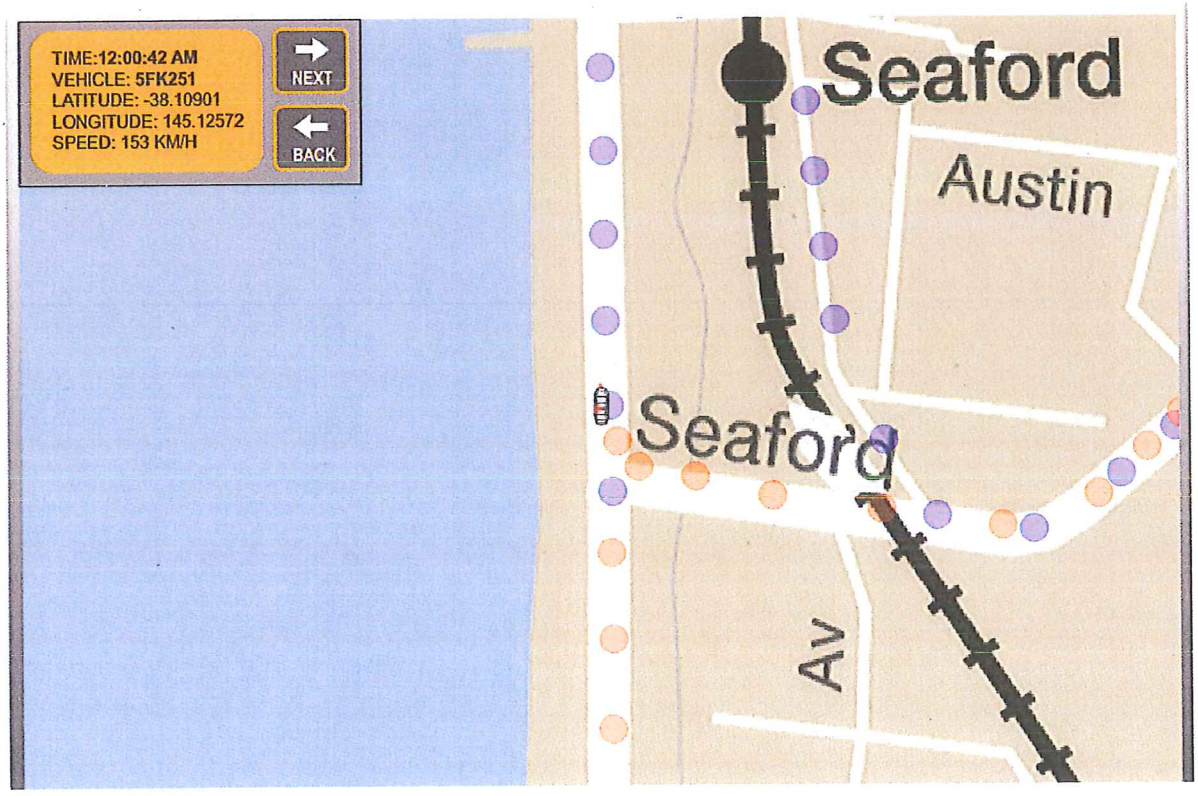
iii. This event occurred within seconds (if not at the same second) according to both the D24 and the Motorola GPS data.

iv. Refer to screen shots below which show Frankton 251's location at 00.00.39 and at 00.00.42, based on the Motorola GPS data and the animation at exhibit 16B.

---

[20] See Exhibit 19B
[21] See Exhibit 16B





i. Example 2:

i. The D24 shows that Frankston 615 announced on radio at 00.02.09:

"Frankston 615, we're behind the primary unit". The primary unit at this stage is Frankston 251.

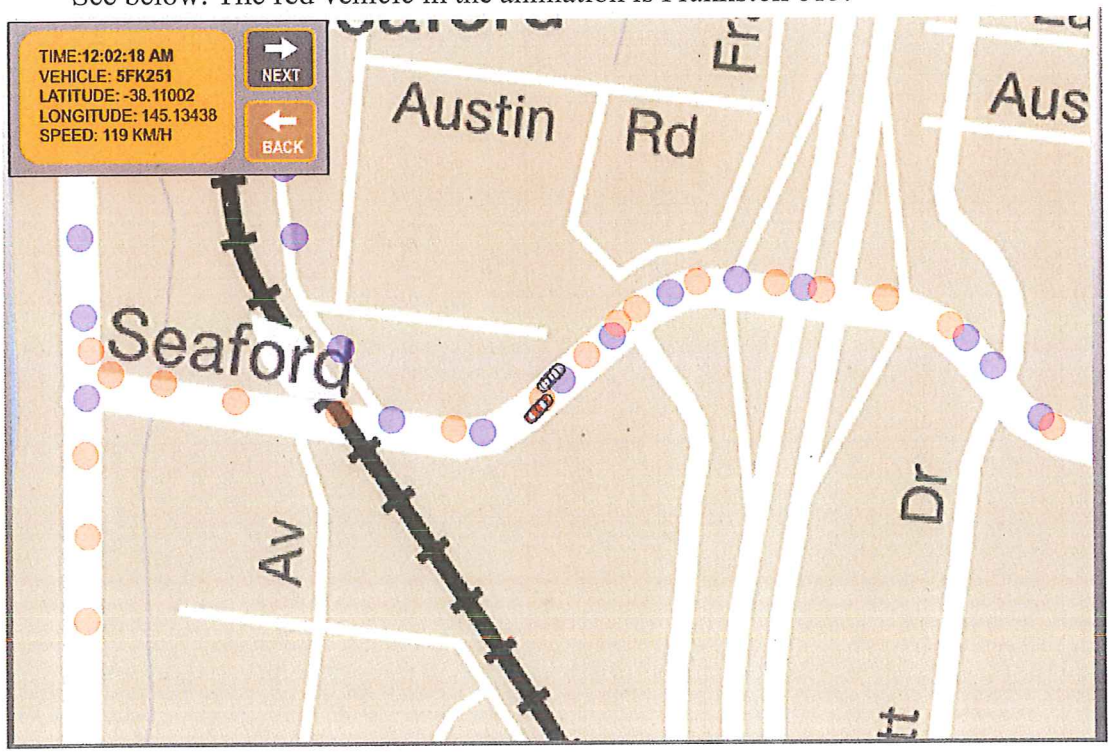
ii. The GPS data animation shows that at approximately 00.02.06 Frankston 615 first takes up a position behind Frankston 251. The D24 narrative is consistent with the GPS data animation. See screenshot of the pursuit animation below.

iii. Note, the purple dots are Frankston 251 and the red dots are Frankston 615.

j. Example 3:

i. According to the D24, at 00.02.18 Hastings 251 (pursuit controller) ordered that Frankston 615 take up position as the primary pursuit vehicle.

ii. The pursuit animation shows that at 00.02.18, Frankston 615 moves to the right of Frankston 251 in what appears to be an attempt to overtake. See below. The red vehicle in the animation is Frankston 615.



iii. The animation then shows Frankston 615 fall back behind Frankston 251 until the overtake manoeuvre eventually occurs at between 00.00.39 and 00.00.42. Senior Constable Orr, driver of Frankston 615, gave evidence

that initially he couldn't take the lead of the pursuit and that he had to wait until it was safe to do so, which occurred around the overpass.[22] That is consistent with what can be observed on the GPS pursuit animation.

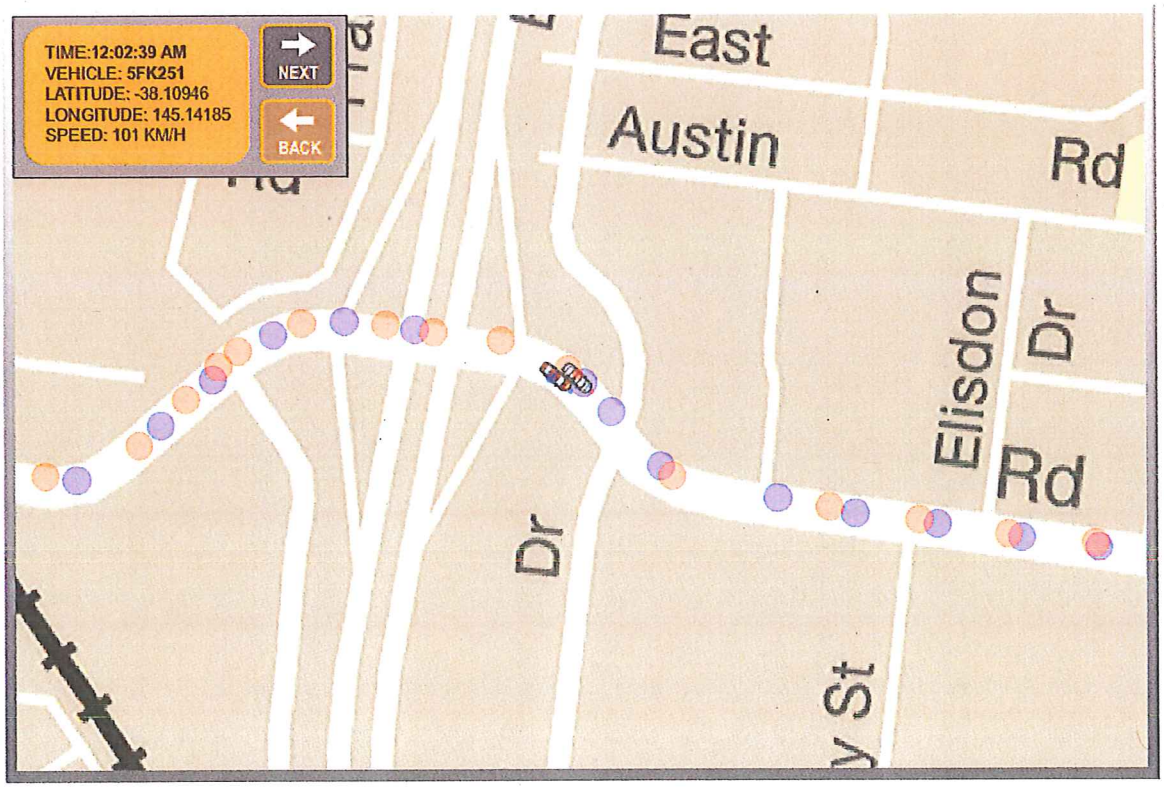
iv. According to the D24, at 00.02.40 Frankston 251 transmitted as follows:

Frankston 251, 615's now taken over primary position. We're still heading north. Seaford Road towards Frankston-Dandenong Road, speeds are 120.

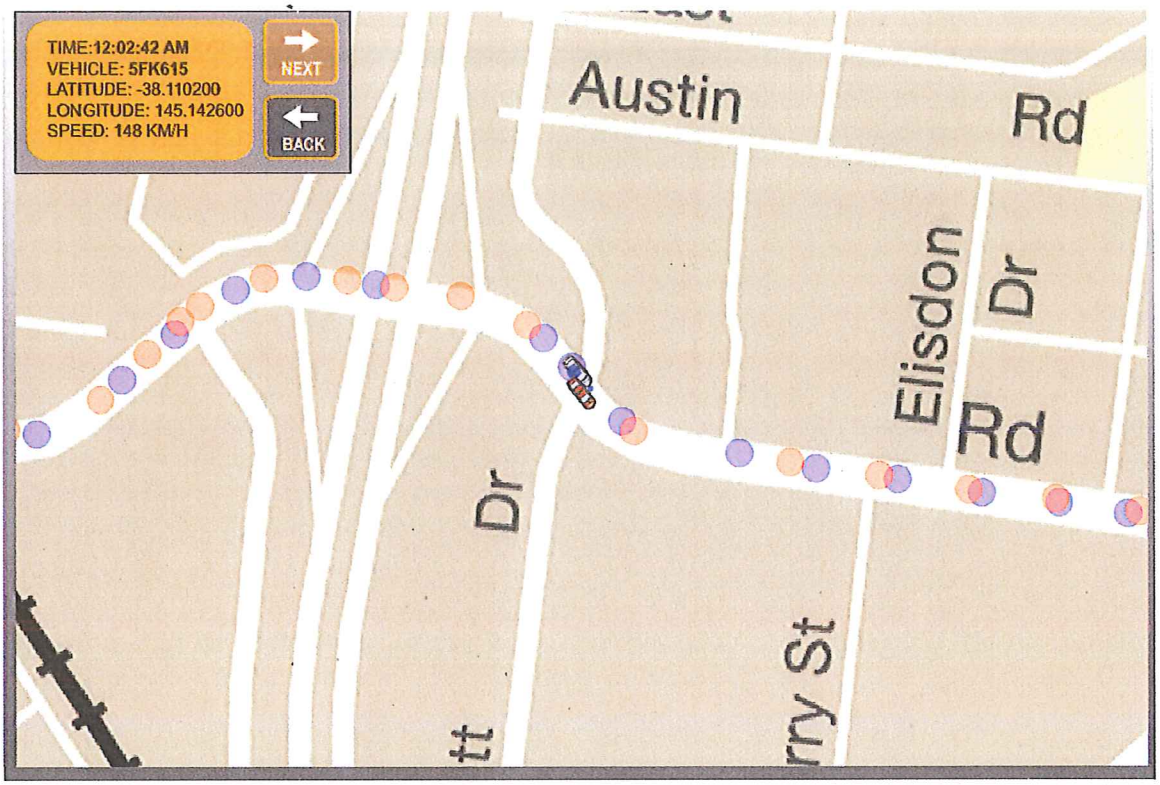
v. According the GPS data and the pursuit animation, at 00.02.39 Frankston 251 is approximately half a car length in front of Frankston 615. And at 00.02.42, Frankston 615 is approximately half a car length in front of Frankston 251.

vi. So the Motorola GPS data shows that Frankston 615 took over lead pursuit vehicle at around the same second that Frankston 251 announces that event as having happened. See screen shots below:

vii. This screen shot at 12.02.42 shows Frankston 615's GPS details for the first time, as the animation was programed to detail the GPS information for the lead vehicle at all times.[23]



[22] See transcript page 1016.
[23] See transcript 809 line 13.



6. Accuracy of GPS plots on the map

a. Mr Sidebottom from Motorola described the margin for error associated with GPS plotted coordinates (location coordinates) as follows:

> *What we're saying is the six metres, it can be anywhere within a circle so it could be further along the road or backwards along the road or laterally, sideways on the road.*[24]

b. As a matter of common sense, lateral error across the road will be more obvious and detectable than would be error along the road.

c. Inspector Ross Oberin gave evidence that one of the things he looks for to confirm the accuracy of the GPS data is lateral movement across the road. Inspector Oberin gave evidence that:

> *So the two things I look for are position on the road laterally. In other words is it tracking off the road, and the heading. So on a map does it appear that the vehicle is actually tracking along the road that it's supposed to be on. In both instances they were tracking fine and there was very little, maybe a metre or so lateral movement, along any part of the road, but in most cases the vehicles were actually shown on the road and on the correct side sir.*[25]

---

[24] Transcript 660 line 27
[25] Transcript page 371, line 17.

d. Inspector Oberin explained further as follows:

> *The accuracy that concerned me was did the vehicles track along the roadway including turns and corners and was the speeds indicated in the data - - -*
> *consistent with the speed I would expect a vehicle to be travelling either along a straight line or on a sharp corner. Your Worship, if it's a very sharp corner I would expect the speed to wash right back to very low speed. The data demonstrated that. On a long, straight stretch in a pursuit, I would expect the speeds to rise to above the speed limit, the data demonstrated that.*

e. Inspector Oberin's observations (and my own observations as these animations were shown in open Court and the coordinates were also plotted on Google maps during Mr Sidebottom's evidence) that the vehicles were tracking on the road, and in most cases on the correct side of the road, provides a practical verification that the MDTs and their GPS functions operating properly and within specified parameters during the pursuit, the subject of this inquest.