Creating a baseline setup for Portland International Raceway

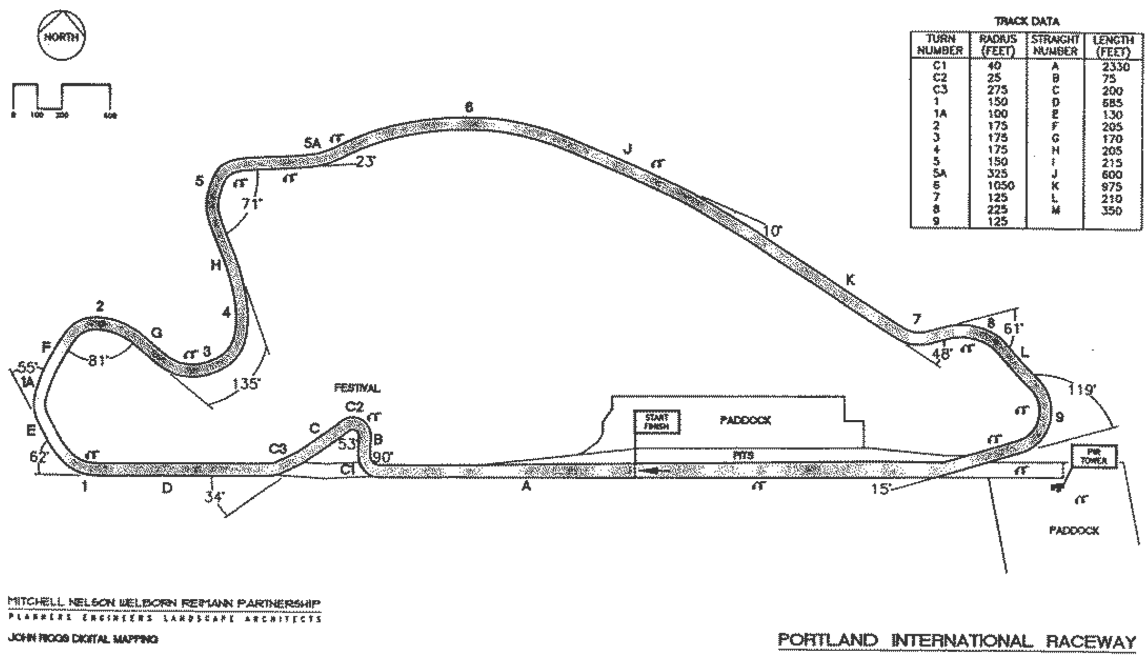
James Hakewill – May/June 2006

This document covers the steps taken to use Bosch Lapsim to perform simple simulations of the Portland International Raceway (PIR) track – the goals being to:

- Set a target laptime for the track
- Work out a starting point for gear selection
- Identify performance-critical sections of the track

Track information

The picture below shows a map of the PIR circuit – the target configuration will include the Festival chicane.



TURN NUMBER	RADIUS (FEET)	STRAIGHT NUMBER	LENGTH (FEET)
C1	40	A	2330
C2	25	B	75
C3	275	C	200
1	150	D	585
1A	100	E	130
2	175	F	205
3	175	G	170
4	175	H	205
5	150	I	215
5A	325	J	600
6	1050	K	975
7	125	L	210
8	225	M	350
9	125		

The track map does not include height or track banking information, but PIR's website lists the following information:

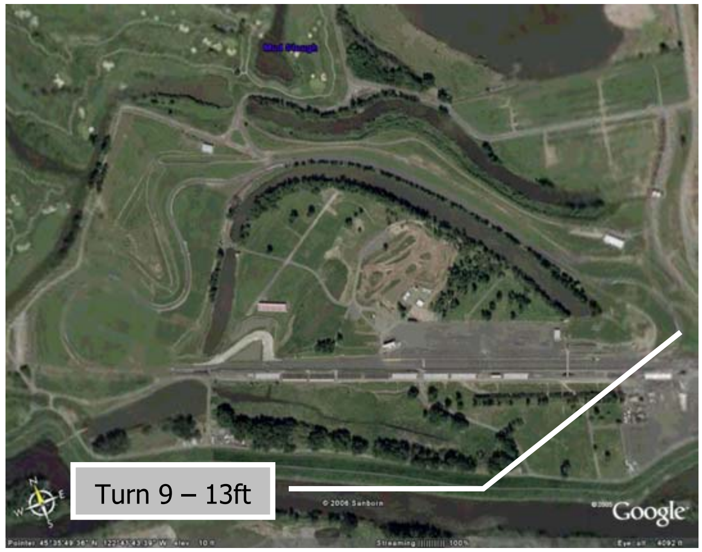
Track Length
- Without "Festival Turns" - 1.915 miles and 9 turns.
- With "Festival Turns" - 1.967 miles and 12 turns.

Track Surface
- Asphalt with a concrete surface for the "Festival Turns."
- No banked turns with only five feet of elevation changes.

Google Earth

The picture to the right is an aerial photo of the PIR track from Google Earth – height data available along with the image indicates that the majority of the track is at 10ft above sea level, except for turn 9, which has a peak of 13ft above sea level. Hence we can agree that there is no significant elevation change.

The concrete section in the festival chicane is apparent from the picture.



Previous results

A survey of previous Formula Ford / Club Ford results at PIR was undertaken to get a range of representative lap times.

Festival track (1.967 miles)

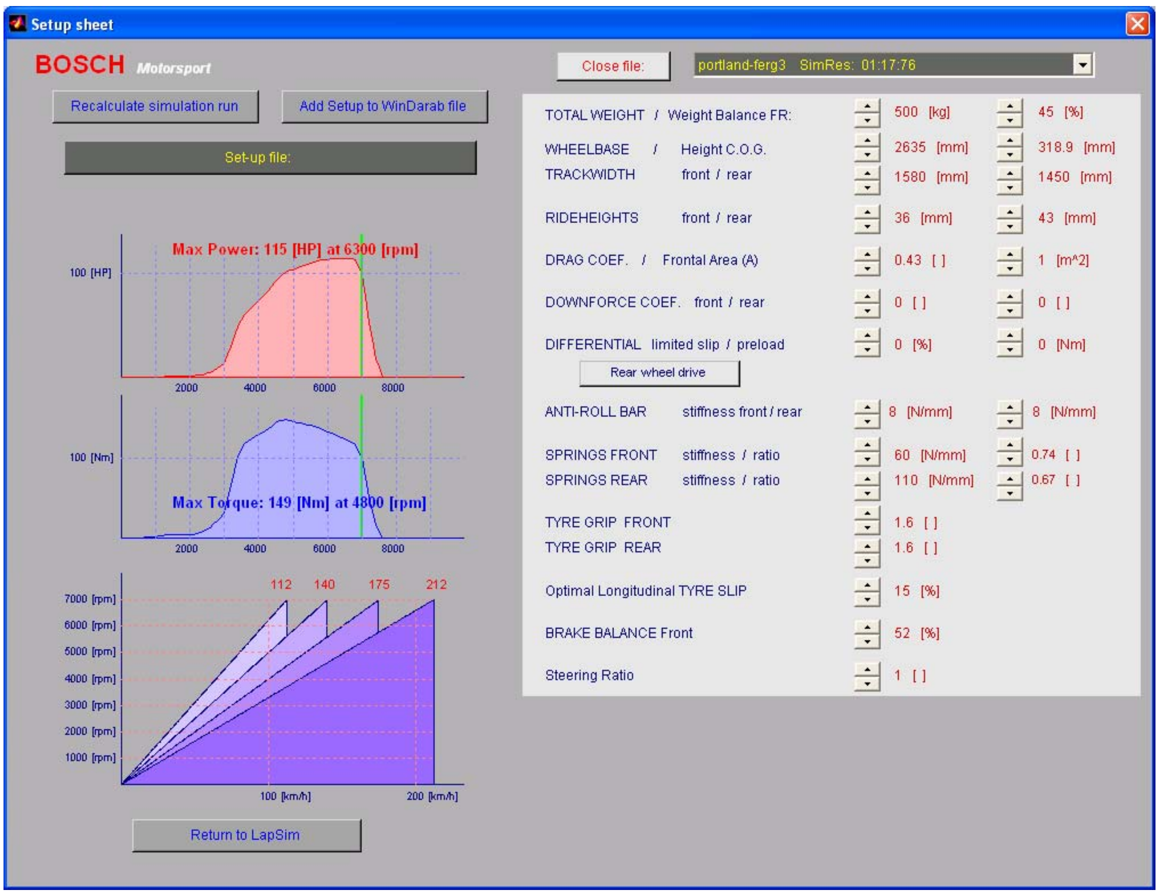
Date	Session	Driver	Car	Lap time	Note
4/17/05	Reg Race	N. Shelton	Crossle 32F (CF)	1:47.482	NWS says 7 mm of rain
6/12/05	Reg Race	L. Bangert	Swift DB1 (FF)	1:21.144	
6/12/05	Reg Race	N. Shelton	Crossle 32F (CF)	1:21.257	
6/12/05	Reg Race	J. Mosteller	Radical 1 (FF)	1:21.525	
6/12/05	Reg Race	R. Jessen	Crossle 35F (CF)	1:22.435	
6/11/05	Nat Race	M. Jaremko	Stohr FF99 (FF)	1:39.967	Wet? No NWS data
6/11/05	Nat Race	N. Shelton	Crossle 32F (FF)	1:40.172	Wet?
6/11/05	Nat Race	L. Bangert	Swift DB1 (FF)	1:46.856	Wet?
5/16/04	Reg Race	L. Bangert	Swift DB1 (FF)	1:22.304	
5/15/04	Nat Race	S. Townes	Swift DB1 (FF)	1:28.744	NWS says 1mm of rain
5/15/04	Nat Race	S. Townes	Swift DB1 (FF)	1:29.697	NWS says 1mm of rain
5/15/04	Nat Race	R. Hill	Crossle 35F(FF)	1:28.044	NWS says 1mm of rain
6/13/04	Reg Race	L. Bangert	Swift DB1 (FF)	1:21.513	
6/13/04	Reg Race	J. Bishop	Swift DB1 (FF)	1:23.012	
6/13/04	Reg Race	N. Shelton	Crossle 32F (CF)	1:23.710	
6/13/04	Reg Race	R. Jessen	Crossle 35F (CF)	1:23.560	
6/12/04	Nat Race	L. Bangert	Swift DB1 (FF)	1:21.780	
6/12/04	Nat Race	J. Bishop	Swift DB1 (FF)	1:22.566	
6/12/04	Nat Race	N. Shelton	Crossle 32F (FF)	1:23.792	
6/12/04	Nat Race	R. Jessen	Crossle 35F (FF)	1:23.771	
6/17/00	Reg Race	S. Townes	Swift DB-1 (FF)	1:20.583	
6/18/00	Nat Race	S. Townes	Swift DB-1 (FF)	1:20.222	
6/18/00	Nat Race	M. Jaremko	Stohr FF99 (FF)	1:20.013	

The fastest FF race lap appears to be Mark Jaremko's 1:20.013, set at the Rose Cup in 2000.

Vehicle model

The goal is to model a Van Diemen RF00 Formula Ford. Accurate data is used as much as possible, but some inputs are necessarily the result of estimates, or 'tuning' to get the model output to match real world data.

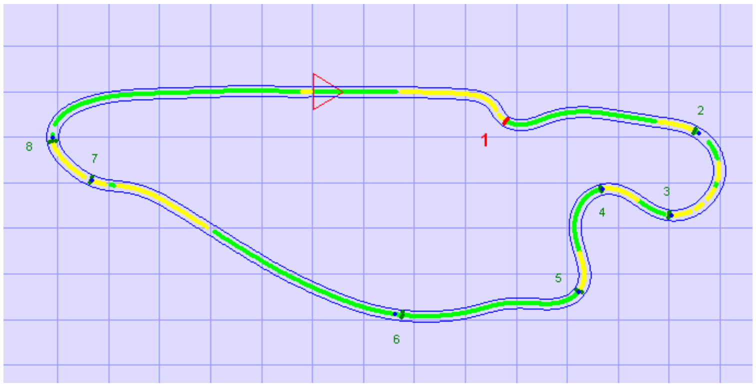
Van Diemen RF00 Formula Ford – James Hakewill driving – photo: Chuck Koehler



In the model data above, the roll bar figures are known to be inaccurate, but that should not greatly affect the overall lap time.

Portland International Raceway – Track data

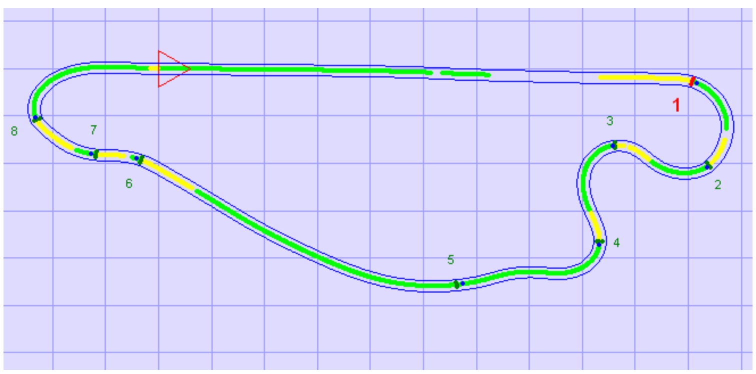
MoTeC Data from David Ferguson's Van Diemen D-Sports Racer was used to generate the map with chicane for Lapsim – shown below.



Speed and acceleration channels were filtered by 0.1s to give a smooth impression of corner radius.

The DSR data showed a total lap length of 10128ft, against the quoted length of 1.967 miles (10385ft). The speed data was adjusted by the ratio of the two numbers (1.0255), to get the total lap distance to be 10385ft.

AIM data from a Mazda Miata (from victorylanedata.com) was used to generate the straight-through map:



The circuit maps are fairly similar but not the same – the effect of the differences will be explored.

Note that the track map generated from David Ferguson's DSR data looks slightly 'fatter'.

In addition, the track also shows a slightly more opened out turn 7/8 before the main straight, and the section after the chicane does not properly continue in a straight line.

Height data from Google Earth was used to add a 1m high incline into turn 9. No banking information was added.

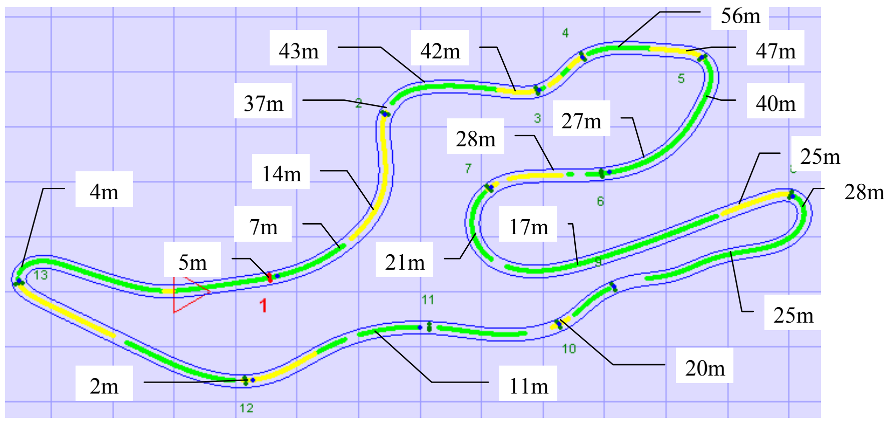
Validation of simulation model – for known tracks

To generate reasonable results, it is necessary to be precise about the inputs to the simulation model. This applies both to the track data being input and the car data used for the model.

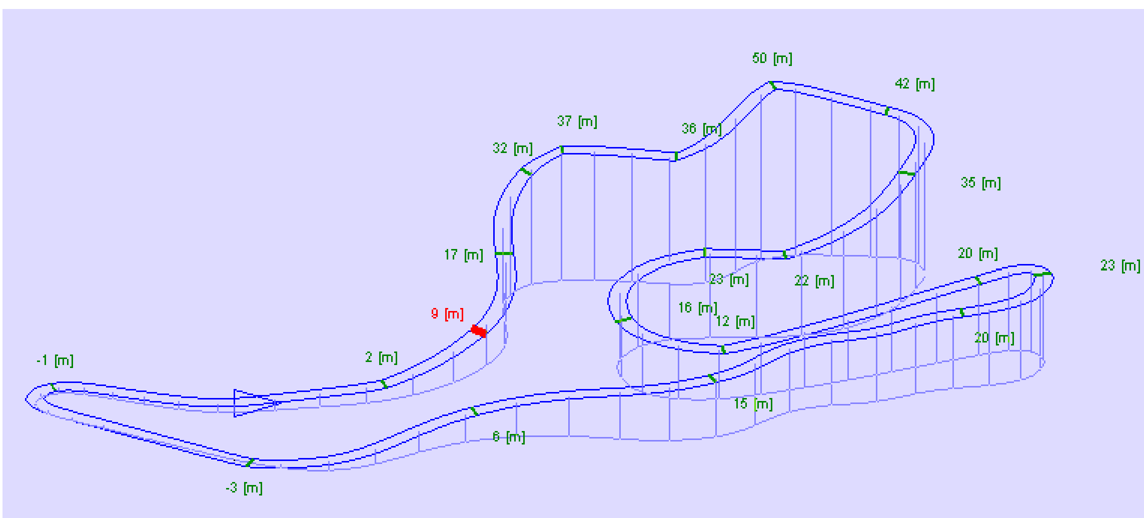
Once reasonable data has been entered into LapSim, an unpleasant process of 'tuning' is undertaken, the goal being to attempt to adjust the performance of the model to match real-world data collected from on-board data logging systems.

Data from an AIM logger fitted to a Swift DB6 FF driven by James Hakewill was used to generate a track map for Infineon Raceway at Sears Point.

Speed data was scaled (by 1.0458) to ensure that the total track length matched the official value for the circuit.

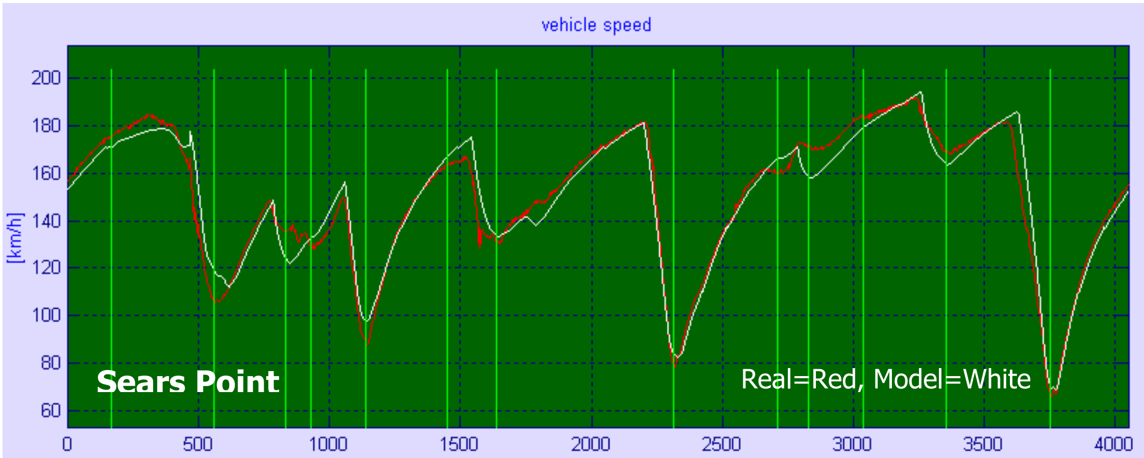


Height data from Google Earth was used to generate the elevation profile of Sears Point:



Data from an architectural drawing of the track was used to enter the track banking: Turn 3 at 2°, turn 4 at 5°, turn 6 (Carousel) at 7°.

Using the baseline simulation model – with data entered as close as possible to real-world values, the comparison in lap times was: Real lap time = 1:41.42, Model lap time = 1:41.60.



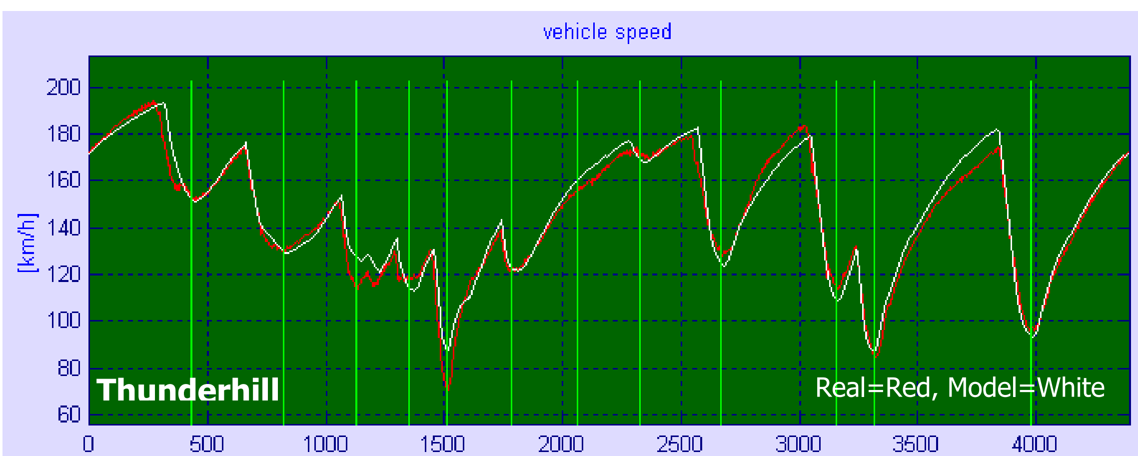
The usual 'fudge factors' used to tune the model are:

- Aero drag coefficient – ideally measured by a 'coastdown test'
    - Value used for Aero drag (Cd x A) = 0.43
- Tire grip – usually obtained from lateral G in a slow-speed grip-critical corner
    - Value used for tire grip coefficient = 1.6

The main differences in the model vs real results are:

- Later braking in most corners
- Much slower entry to turn 8a – this may be as a result of some weirdness in the lateral G data loaded to make the model. Filtering of lateral G before loading may help.

Using the same car model, with a similarly created track model for the Thunderhill Park circuit, the results were: Actual lap time = 1:52.37, Model lap time = 1:51.44.



Another track for which a model is available (with height and banking data) is Laguna Seca – however no real FF data was available. The Lapsim result for the Laguna Seca model was 1:32.1, which is a shade faster than the FF track record of 1:32.4.

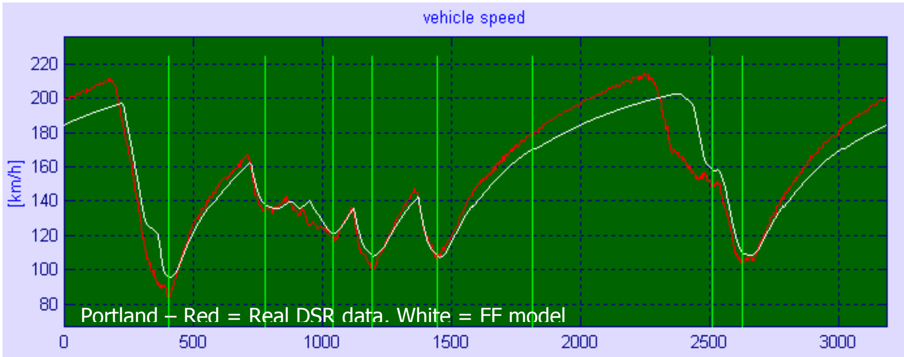
Based on the limited results from by these two known tracks, it seems plausible to suppose that the Lapsim model parameters are reasonably accurate for a 'ballpark' idea of lap time ±1% or so.

Portland track model results

With the baseline car model, using gear sets for Thunderhill, the initial lap time result was a surprising 1:17.76s. The result was surprising since the fastest FF lap found in the survey was 1:20.0.

If the overall grip level of the track is reduced from 100% to 90%, the lap time is increased to a figure of 1:20.01s. However, this doesn't seem like a good explanation for the unexpectedly fast lap.

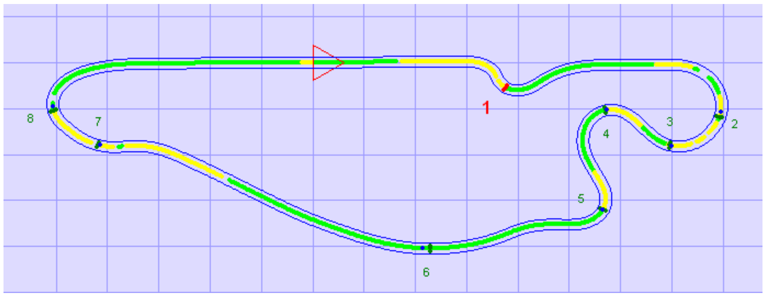
Comparing the real data from David Ferguson's DSR to the data from the FF model, it is possible to come up with some suggestions as to why the model is not behaving as expected.



For some reason, the Formula Ford model (white trace) is capable of generating more cornering force than that measured from a DSR with a rear wing, diffuser, flat floor and front splitter – this seems slightly unrealistic.

The suspicion is that something has gone awry with the combination of measured lateral G and wheel speed used to generate the track model. The wheel speed has been scaled (+2.55%) to ensure the proper track length – this would affect the calculated corner radius. However, the map produced from the unscaled speed data generates very similar results. We will therefore look for a problem with the lateral G input.

When real data is first loaded into LapSim, it is possible to enter an offset value for lateral G, to overcome a static error in the measured data. Different values were tried until a new map was generated where the front straight continues in a straight-on direction after the chicane:



The offset value used to create the map to the left is 0.35 ms^{-2}, which is 0.036G, a fairly small error in the grand scheme of things.

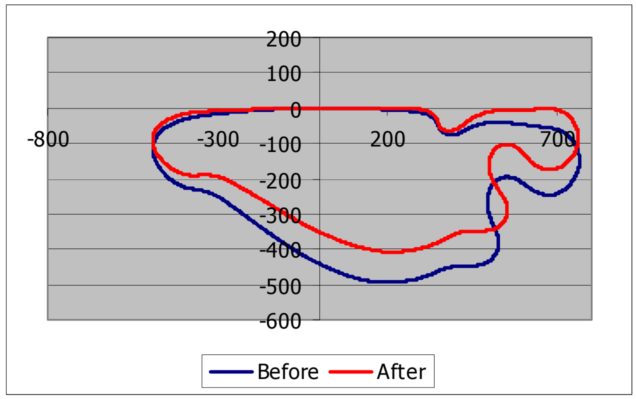
Along with applying the offset, LapSim also scales the lateral G trace in order to 'close' the map – in other words to ensure that the end of the lap is at the same X,Y co-ordinate in space as the start of the lap. The scaling factor calculated by LapSim was 1.129 – which seems like a very large fiddle factor for lateral G.

When drawing a track map from raw data, it is expected that fiddle-factors will be calculated in order to make the lap look correct. This is due to the large cumulative errors that build up over the course of a whole lap, due to small inaccuracies in measurement at each sample point – at 50 or 100 samples per second, the effect of the errors builds up fast.

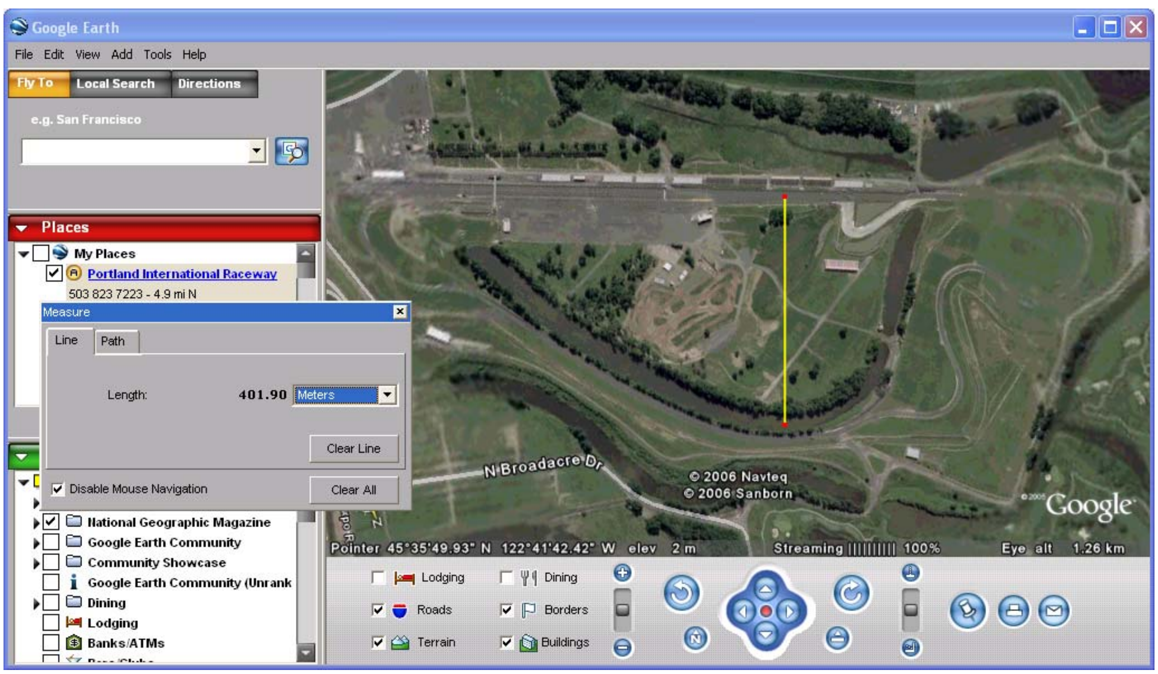
The fiddle factors when working out how to draw a map are used for the following:

- To make the X,Y co-ordinates of the end point the same as the start point
- To make the sum of all the changes of heading add up to 360 degrees, so that the direction of travel at the start is the same as at the end

The chart to the right shows a map calculated using an Excel spreadsheet (with the same input data supplied to LapSim), before and after the correction factors were applied (LatG offset of 0.35, LatG scale of 1.129).



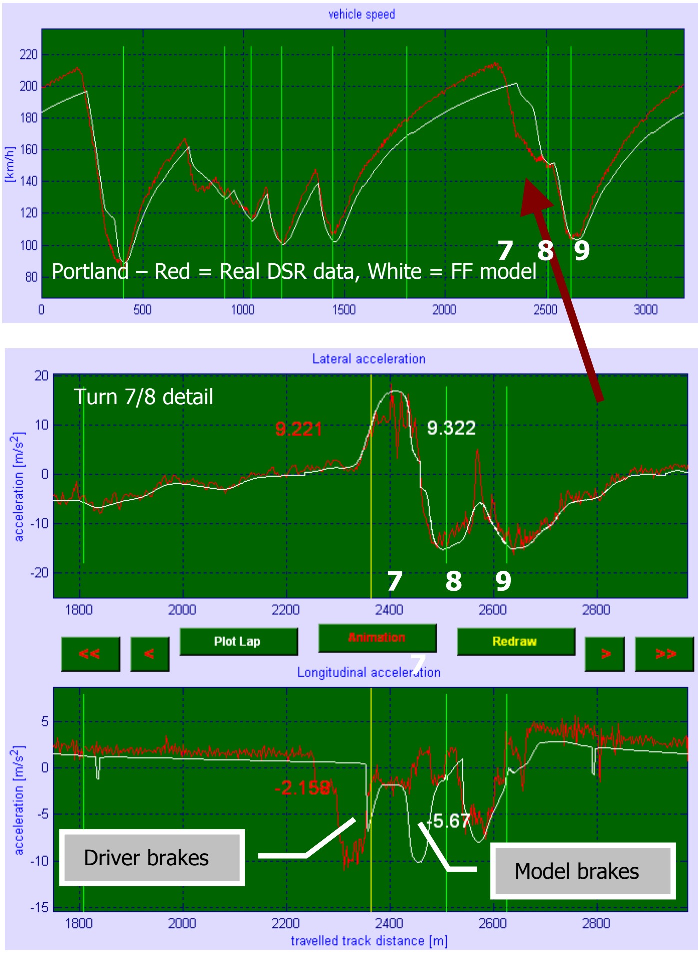
As another sanity check, we can measure the distance between the front straight and the opposite side of the circuit at the widest point – and compare between our corrected map and Google Earth's map. In the corrected Excel map shown, the distance is 407m.



The same measurement made using Google Earth also appears to be around 400m – so the correction factors applied to the map now seem reasonable!

Using the adjusted track model produces a Formula Ford lap time of 1:19.81 – certainly closer to a realistic result – and useful enough to do some data analysis, or make some wild stabs in the dark at least.

PIR track sections – big braking zones and corner entry



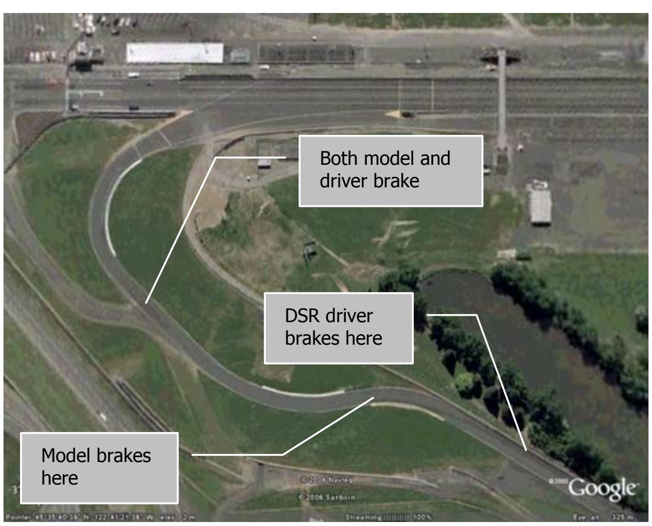
Looking at the comparison of the FF model with the real DSR data, it can be seen that the model is more aggressive on corner entry where there is a complex combination of braking and cornering required – especially going into the chicane and turn 7/8.

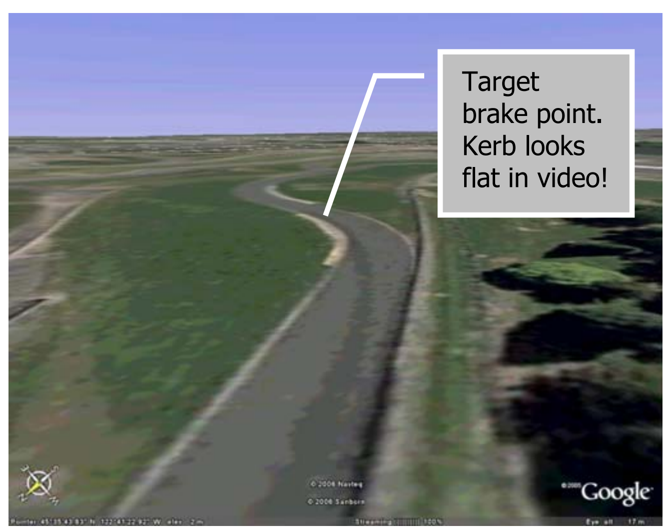
In the real data, the first big brake is done before the entry to turn 7 (the first part of the complex), then there is a second brake after turn 8 for the slowest part – turn 9.

In the model there is a tiny brake for turn 7, and a big brake is done before turn 8, whilst the car is transitioning from a max-G left turn to a max-G right turn.

Carrying good speed through turn 7 into turn 8 is clearly a critical part of a good lap time at PIR – the area lost from under the speed curve as a result of an early brake is large.

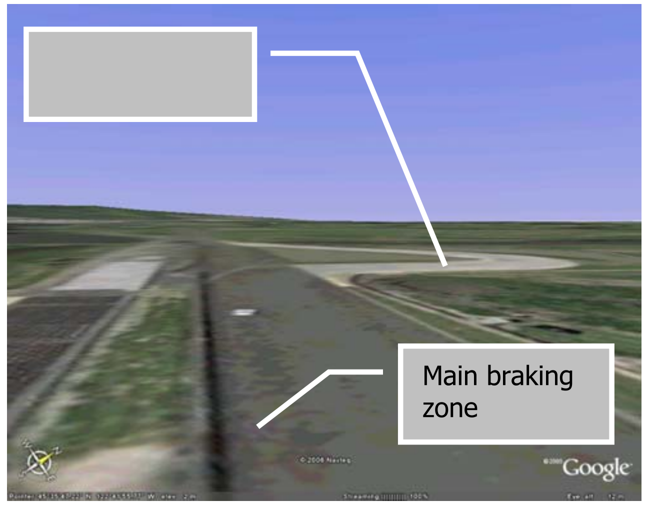
Area under the speed graph directly correlates to lap time.

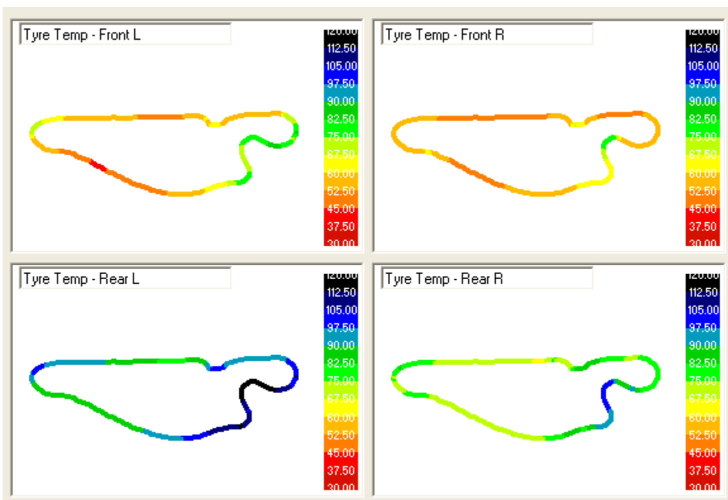




A similar effect is seen in the chicane at the start of the lap – the model brakes just enough to make the first part of the chicane, then brakes a little more to make the second part of the corner.

A real driver tends to brake once for both parts of the turn. However it should be possible to concentrate on carrying speed into the chicane – potentially even at the expense of speed into the short section of straight following the chicane.



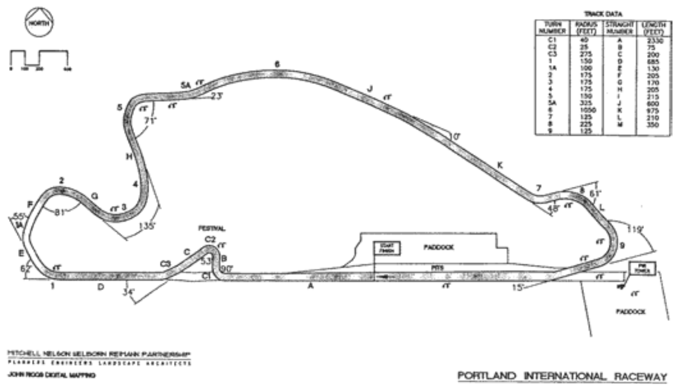


The DSR data from David Ferguson included tire temperature data – it is interesting to see where on the track the tires are relatively warm and cold.

Clearly the left-rear tire is working hard – it is by far the hottest of all four tires.

Notice how the tires cool on the straights, and gain and hold temperature through the twisty left-right section following the chicane.

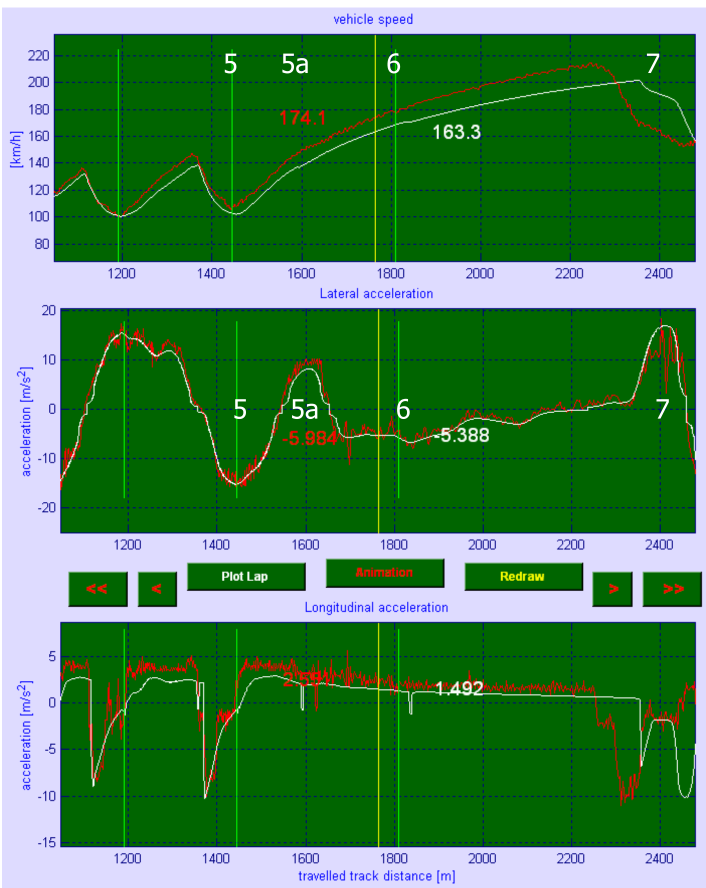
PIR track sections – turn 5 to turn 7



The only long straights on the track are:

- Front straight after turn 9
- Back straight after turn 5

The right turn onto the back section of the track (turn 5) is preceded by a series of right-left corners. All four tires will be at their hottest of any point on the circuit at the exit of turn 5, based on the DSR tire temp data.

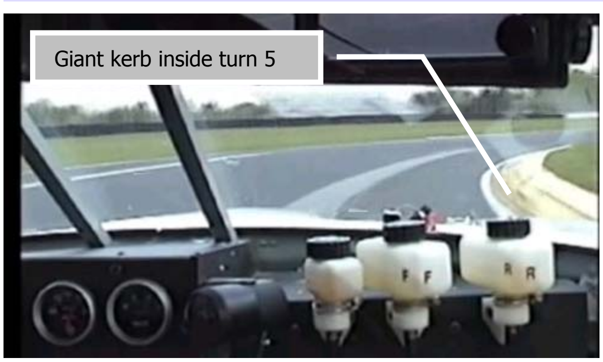


Neither turn 5a nor turn 6 will require maximum lateral acceleration or a throttle lift. The scheme will be to minimize tire scrub and steering input.

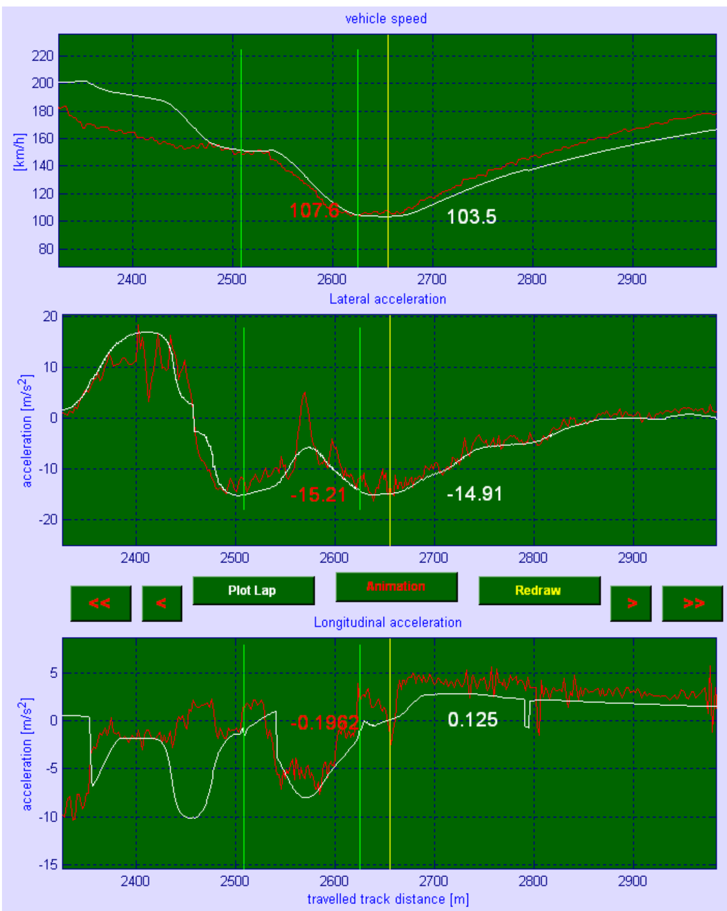
Good speed on the back section of the track will be determined by:

- Exit speed from turn 5
- Minimizing scrub and steering input through turns 5a and 6
- Aero drag - don't go right up to the wall to avoid drag from open wheels
- Static toe

From a video found on the Google Video system, it appears that the inside kerb of turn 5 is very high – not somewhere that a Formula Ford would want to go.



PIR track sections – front straight

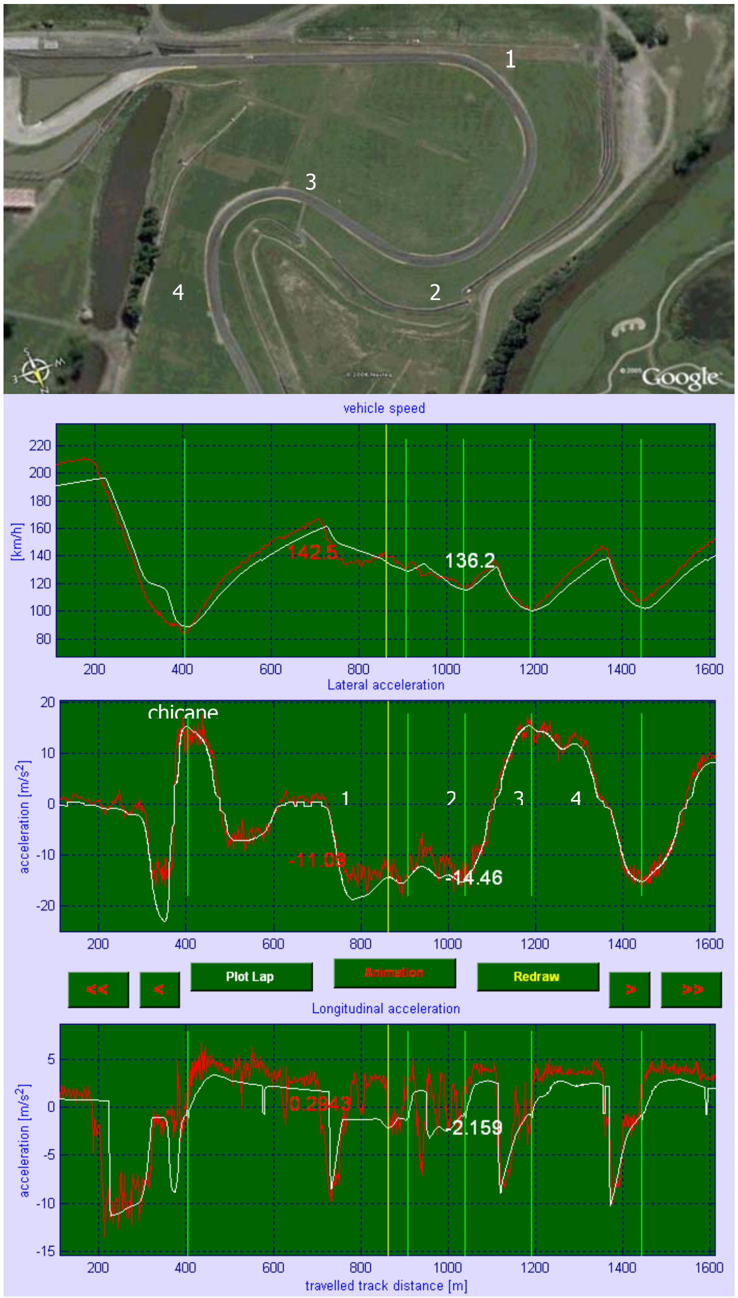


There does not appear to be very much exciting to say about turn 9 and the entry to the front straight.

We can say some normal stuff – Speed on the straight will be determined by:

- Exit speed from turn 9 - 100% throttle point - inside wheel spin
- Minimizing scrub and steering input on exit
- Aero drag - Don't go right up close to the wall, to avoid drag from the flow around open wheels
- Static toe

PIR track sections – turns 1 to 4



The twisty part of the circuit looks to be particularly interesting.

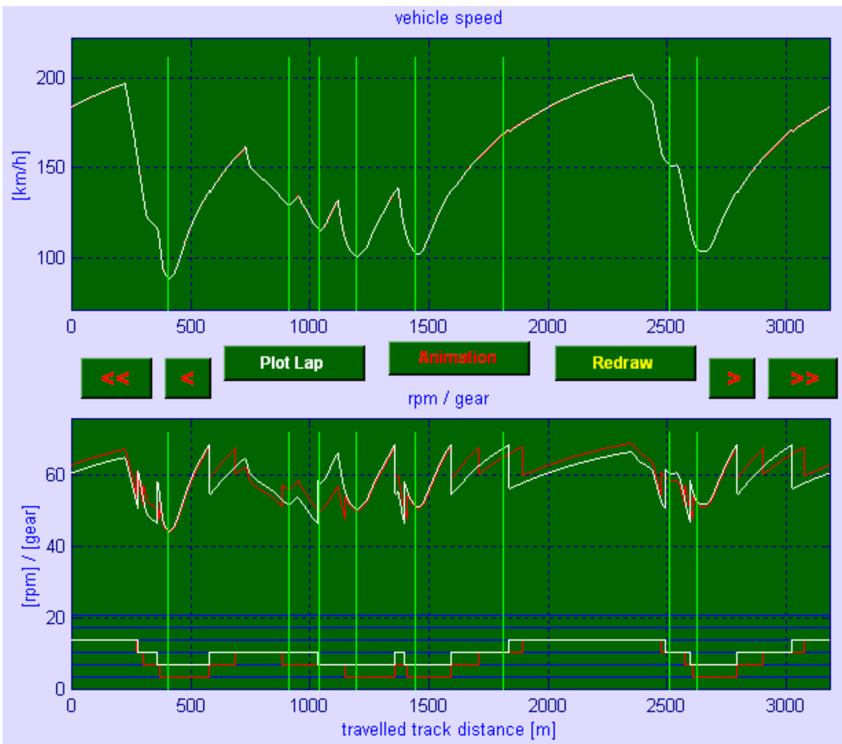
The majority of time in this complex of corners is spent in the section from the chicane to turn 2. A small brake is required for turn 1 – and it seems that some small period of throttle could be applied before the second braking area for turn 2. Maximizing speed through this first section will be important for lap time.

From the accelerations trace below it can be seen that the braking area for turn 3 is at a point where the car is changing from a right to a left turn – trail-braking and good transitional (i.e. shock) performance is required for a good balance here.

Gear Selection

The book "How to Build and Maintain Competitive (yet legal) Formula Ford 1600 Engines" by Jake Lamont and Tom Andresen has a section for gear ratios for a number of tracks. The set listed for Portland International Raceway, as supplied by Tom Rust Engineering, is in the table below – it's not clear from the book if these are for the straight-through or chicane configuration.

Source	Diff	1st	2nd	3rd	4th	Lap time	Trace
Installed set (Thunderhill)	10:31	16:34	17:29	22:30	24:27	1:19.76	White
Rust (Jake's book)	10:31	19:32	21:31	22:29	24:28	1:19.81	Red
Experimental	10:31	18:32	21:31	22:28	24:27	1:19.80	-



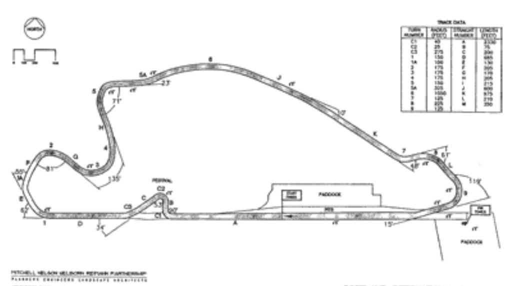
Using Tom Rust's gear ratios, we have a longer first gear – and a shorter fourth.

The slower simulation model time could well be as a result of the increased number of gearshifts.

Setup notes

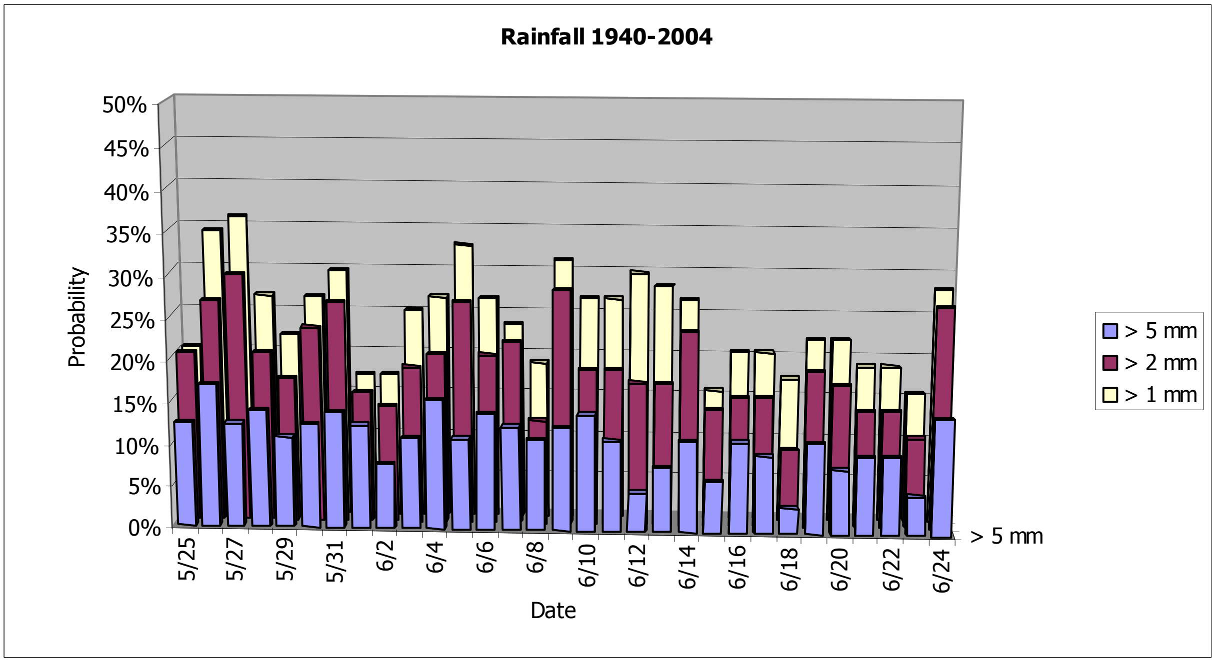
From the track map it can be seen that all the significant turns at PIR are right-handers, with the exception of turn 3 – which is followed by a very short track segment.

It would be worthwhile to consider an asymmetrical car setup – especially for camber.



Weather

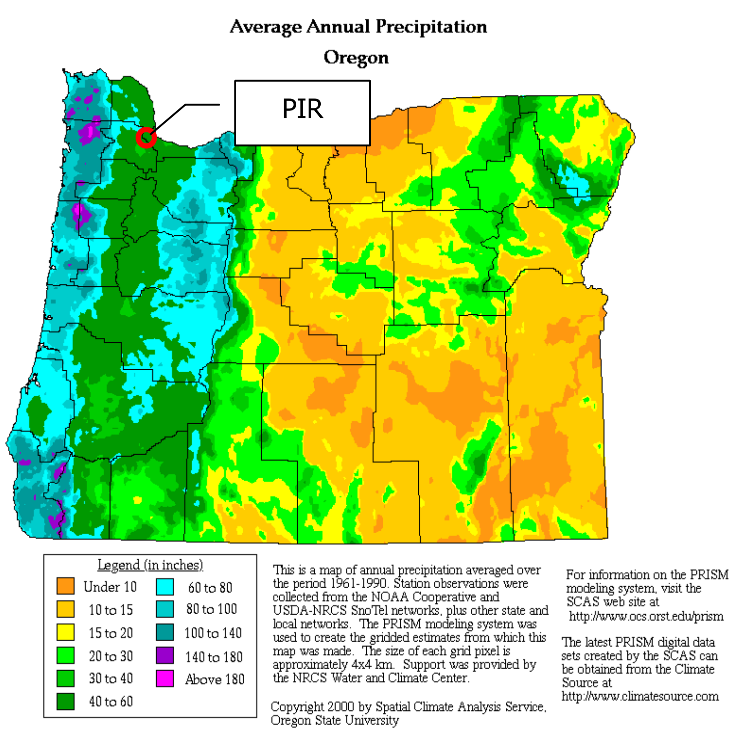
Data from the National Weather Service for Portland rainfall over the last sixty years was used to estimate the probability of rain during the early-June race weekend, and is shown below.



From the chart it is apparent that for the race weekend in question 6/9-6/11 it will be prudent to be prepared with both a good full-wet and a beater/intermediate set of rain tires.

- ~30% chance of >1mm
- ~20% chance of >2mm
- ~10% chance of >5mm

A wet-weather setup for the car also will be a necessity.



Actual Track Time

The car was run at Portland during three days – a pre-race open test session, and two days of the Rose Cup SCCA National race weekend.

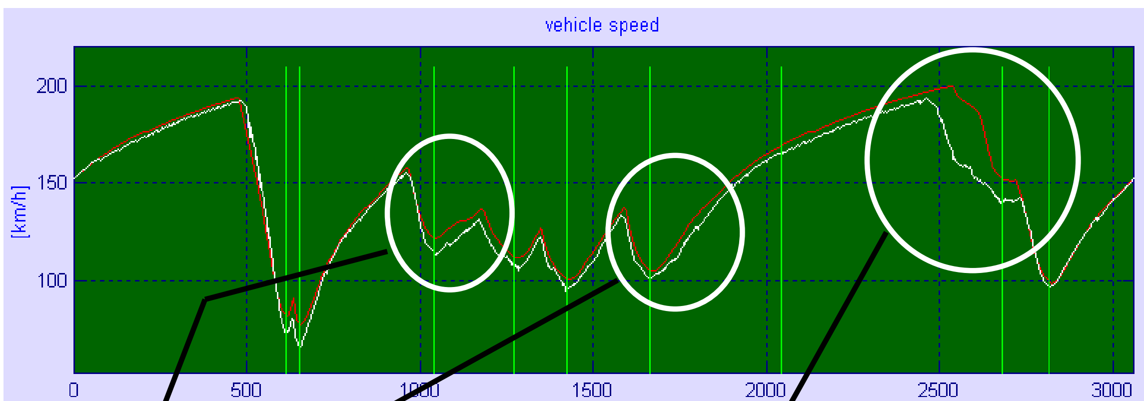
During the test day, the primary goals were to:

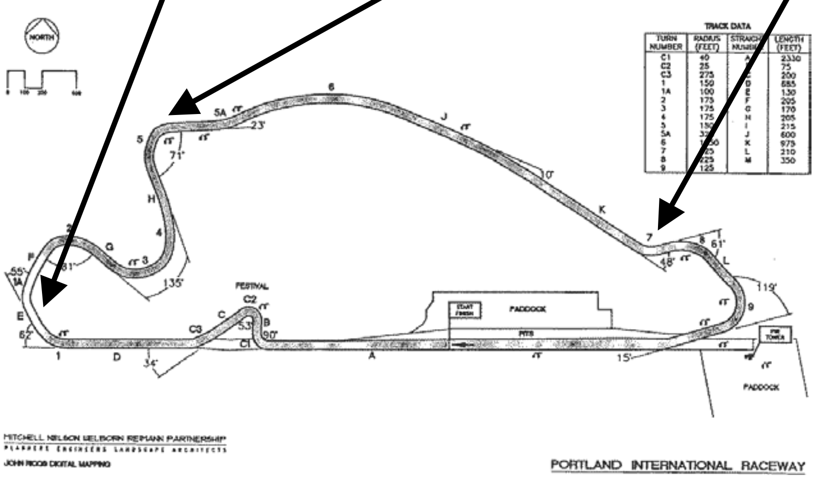
- Learn the track
- Get a decent idea of tyre temps, pressures, and cambers
- Check out gears estimated from LapSim (worked out well!)

Once the driver was getting close to a reasonable lap time (in the high 1:20s), and the tire temps looked good, LapSim was used to see where more time could be gained.

The raw data from the car was exported from the AIM software, converted to CSV, and loaded into LapSim.

Rather than using the track model generated for the original runs, the new data was used to create the track map – to avoid the need to adjust beacon positions.





The simulated lap time produced was 1:18.94 against a real lap time of 1:20.75. The three key areas for improvement were identified as:

1. Entry to turn 1
2. Exit from turn 5 onto back straight
3. Esses at end of back straight

These were used as targets for improvement. Whilst it cannot be said that there was significant improvement in the esses, the improvement came from turns 1 through 5. The improved qualifying lap time of 1:19.899 was good enough for 2nd place, around 0.3s off the pole time.

As always, there is still plenty of room for improvement from the driver, and also in generating more grip from the car. There is certainly more time to be gained from the intimidating entry to the esses.

The notes produced on performance for the track were generally useful, but the most useful tool at the track in improving lap time was a downloaded video for a fast lap of the track. Having driven the track a small amount, watching the video made it easy to identify where the corner apexes should be!

Riding the flat kerb on entry to the esses

Just touching the high kerb on the exit

The race was interesting – changes intended to improve the car's slight oversteer handling had resulted in a flat slide everywhere.

The race was spent mostly trying to chase down the 'local guy' after taking the lead on the start and losing it again at the end of the first lap. However, the 'local guy' spun towards the end in the esses, giving just enough time to take the lead and stay in front until the end!