

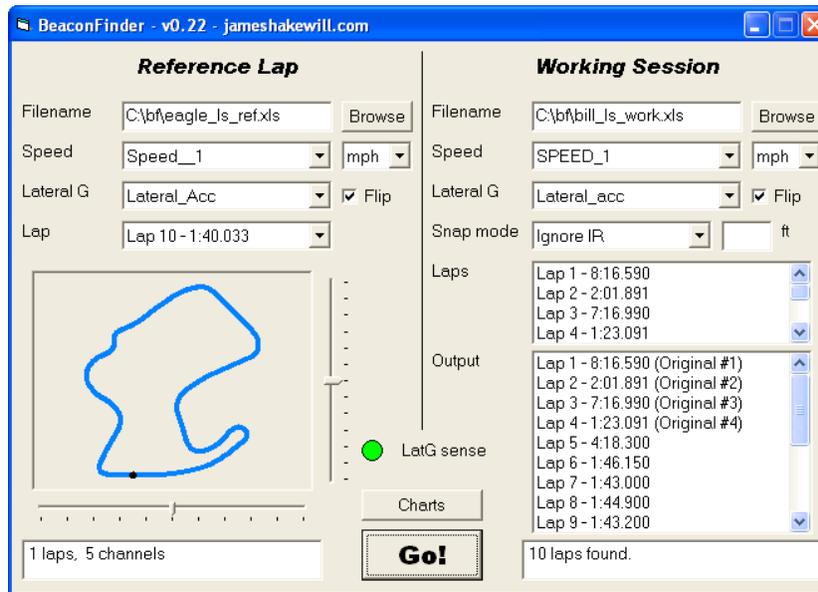


photo: Tom Duncan

## BeaconFinder introduction

BeaconFinder has been created to allow you to replace missing or damaged beacon hits in your race data. A known-good 'reference' lap is used to find missing lap start points.

BeaconFinder can also calculate the beacon shift between two sessions – allowing easy overlaying of race data.



BeaconFinder can be useful in many different beacon-related circumstances:

- No beacon hits
  - Nobody put a beacon out, or somebody forgot to turn it on
  - Someone took the beacon away, or it fell over (was it pushed?)
  - The batteries went dead
  - The receiver was on the wrong side of the car
- Occasional missing beacon hits
  - Another car blocks the beam as you pass
  - Low sun overpowers the beacon
  - Weak beacon signal
    - Batteries getting low, Bad angle, Beacon too far away
- Multiple beacon hits per lap
  - Blockout time too short
- Hits from multiple beacons
  - After missing the first beacon on the pit wall (reasons as above), you might get a hit from a second beacon if there is one

- When there are multiple beacons on the pit wall, the position of the first beacon changed during the session (e.g. someone took it away)

Best results are obtained using a known-good reference lap from the same car and driver on the same day. However, it is possible to extract lap times using a reference lap from a different class of car with a different driver, and even to get approximate lap times when no reference lap is available.

BeaconFinder reads lap and session data in text format – as written by the AIM RaceStudio2 Export-to-Excel feature.

A list of lap times is produced, which you can use to edit lap times in the RaceStudio2 software. This version of BeaconFinder cannot directly read and write AIM .drk format files.

Unfortunately, BeaconFinder can't tell you how to find the beacon that you left behind at the track.

## **How does it work?**

BeaconFinder uses speed and lateral G data to calculate corner radius for each point in the data – a similar technique is used to create track maps. If the same racing line were followed on each lap, the same corner radius trace would result, irrespective of speed.

Beaconfinder searches the corner-radius data from the working session for the best matches with the corner-radius data from the reference lap. The lap-end points are thus calculated – for the beacon location used for the reference lap.

## **How accurate is it?**

When using a reference lap from the same car and driver, the majority of calculated lap times are within  $\pm 0.2s$  of the originals. Under ideal conditions, calculated laps can be less than 0.1s away from the original lap times.

## Why not forget about beacons?

Use of IR beacons (or inductive loop hits) is an accurate method for measuring lap times. GPS offers the prospect of better accuracy in future systems. Reconstructing lap times from lateralG-vs-distance is not ideal due to the errors and inaccuracies inherent in speed and acceleration measurements. For example, each lap has a different measured distance, due to:

- Variations in racing line
- Variations in distance calculation due to
  - Wheelspin and locking
  - Slip angle
  - Tire growth
  - Sampling rate
  - Analog-digital converter accuracy
  - Rounding errors during calculations

The accuracy of BeaconFinder results can be also affected by variations in corner radius due to:

- Variations in racing line
- Warm-up and cool-down laps
- Pace-car laps – especially when weaving to warm tires

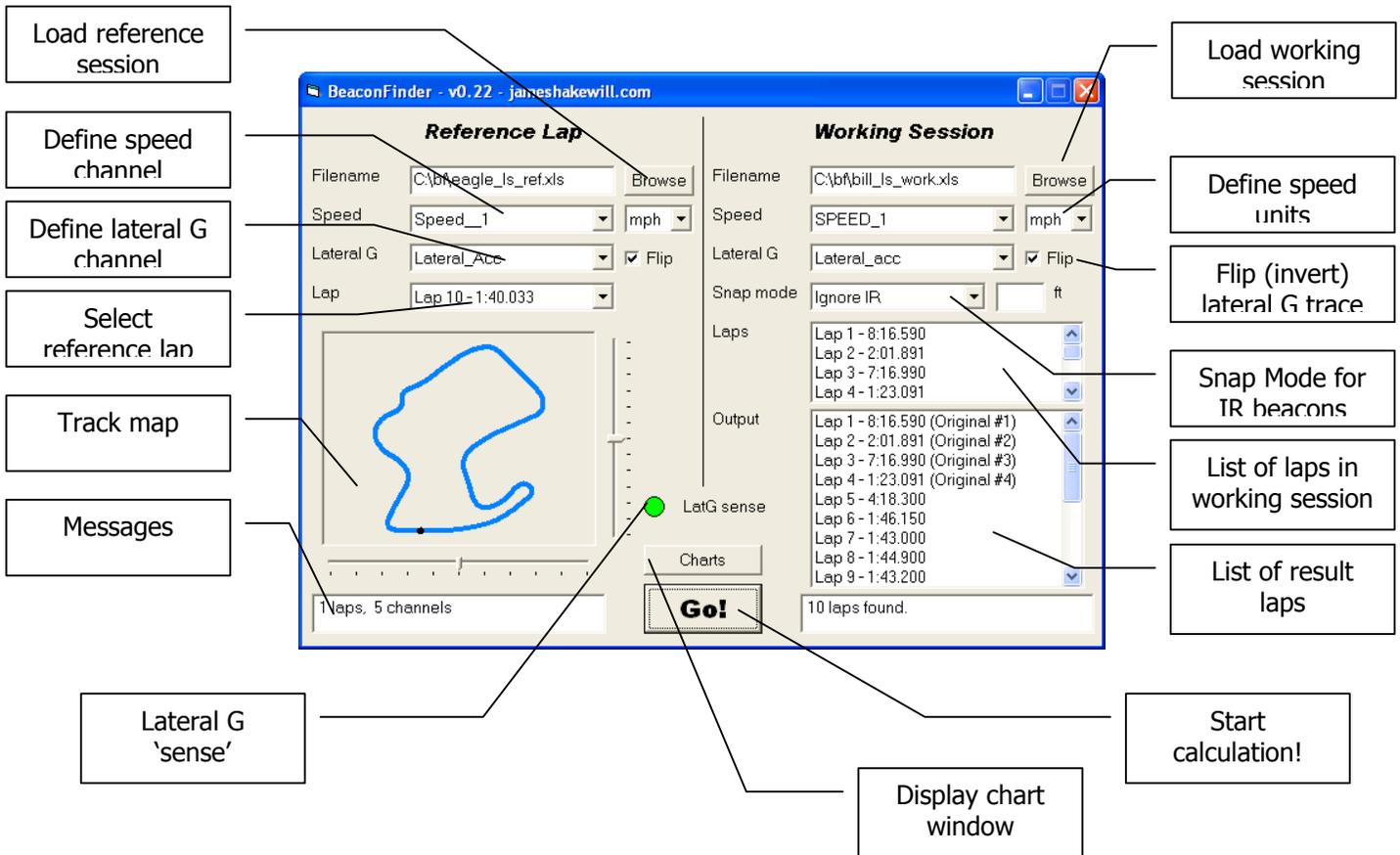
Whilst it is possible to get good matches to the original lap times from BeaconFinder, an external beacon is still the most accurate way to mark lap positions. With one beacon hit per lap, any cumulative errors are reset when the beacon is passed, and are not allowed to build up over the entire session.

Note that in earlier versions of AIM software (e.g. version 2.20.10), it was not possible to perform a ‘beacon shift’ on a session where the lap times have been edited. This makes comparison of two sessions that have been edited very tricky – since it is not possible to shift the beacon in either session. The only workaround is to regenerate the lap times of the adjusted session using a reference lap from the session to be compared against.

## The BeaconFinder window

The main window is split into two halves:

- On the left hand side – the reference lap
  - Defines a single lap to be used as a reference for locating lap start points in the working session
  - The desired lap is selected from all laps present in the session
- On the right hand side – the working session
  - Defines an entire session to be searched for lap start points
  - Any lap times already recorded are shown
  - Can be the same file as the reference session



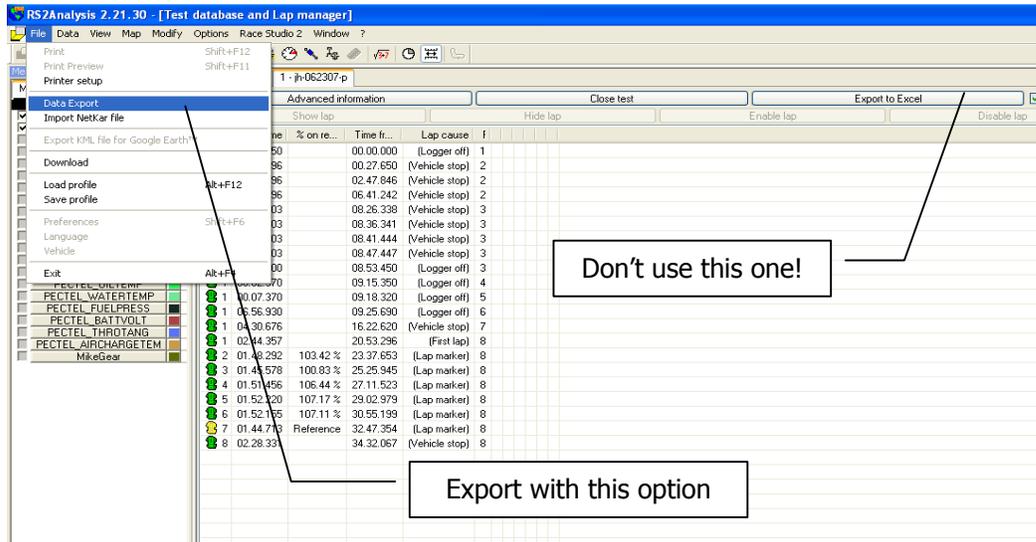
Calculation is started with the 'go!' button. Due to the number of calculations required (which increase with session sample rate), this may take some time!

The resulting output lap times are displayed in the result laps list box, on the lower right of the window.

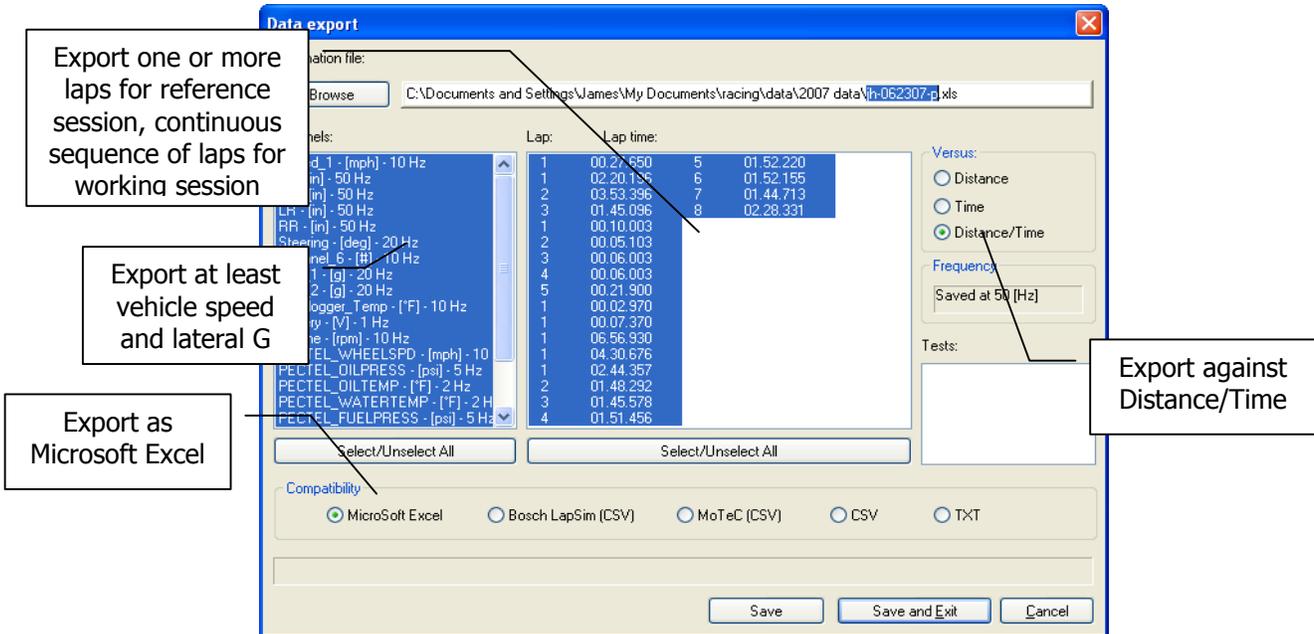
# Exporting data from RaceStudio2

BeaconFinder reads data files as plain text, as exported by AIM RaceStudio2. This version has been tested with RS2 v2.21.30.

In RaceStudio2, load the desired session then select “File -> Data Export” – don’t use the ‘Export to Excel’ button in the Lap Manager, as this just writes a list of lap times.



Next, the laps and channels to export are selected – always export as Excel and against Distance/Time or an error will result when BeaconFinder tries to read the file.



When deciding what to export, note that the minimum requirements for BeaconFinder are:

- Vehicle speed channel (in MPH or KPH)
- Lateral G channel (in G)
- Exported against “Distance/Time”
- Filename extension – should end in “.xls”
- Laps
  - At least one for reference session file
  - Continuous series of laps for working session file
  - Include warm-up and cool-down laps
  - If unsure, just include everything!

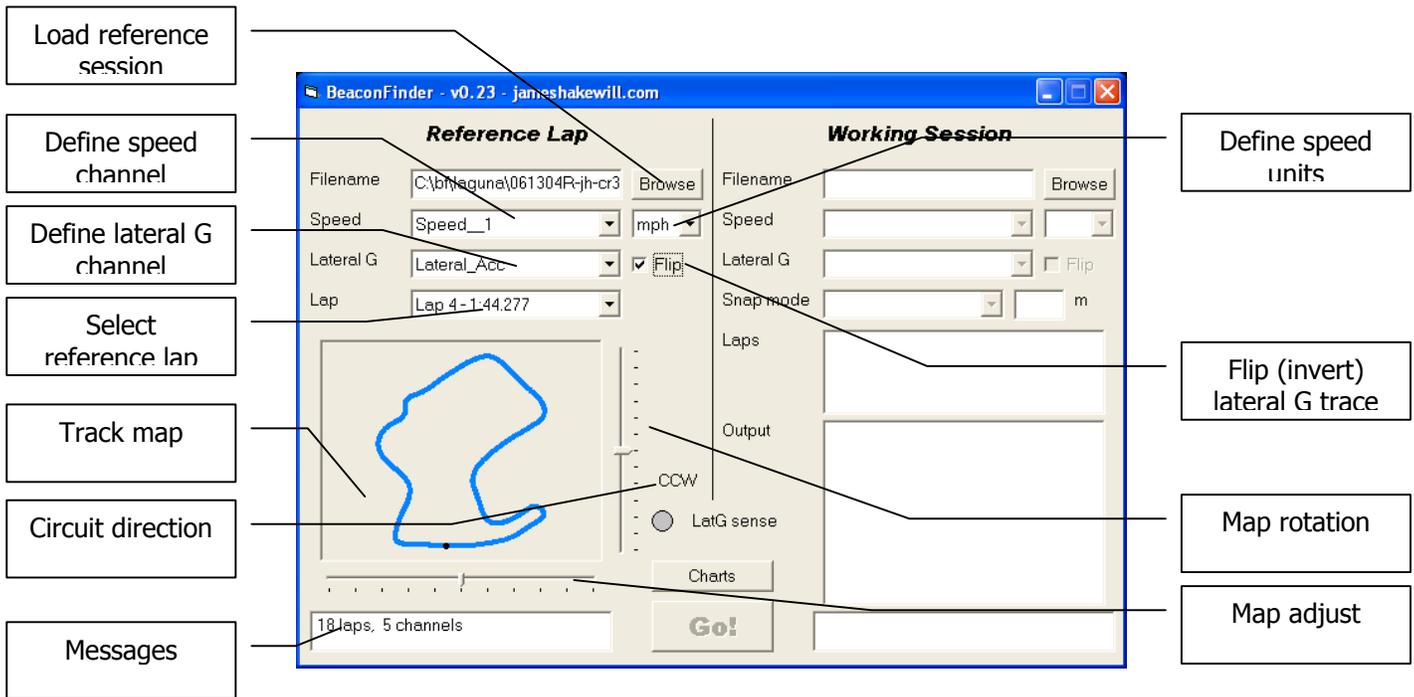
More data channels can be included, but are not required – and cannot be displayed on the charts.

## The Reference session

To load a reference session, click on the 'browse' button in the Reference lap section of the BeaconFinder window. Select the desired file and click OK.

If the file could not be loaded, or something bad happened, a message will appear to that effect. The most likely causes of errors are:

- The file selected was not exported from AIM RaceStudio2
- The data was not exported against Distance/Time
- Something bad happened inside the program



If the file was loaded successfully, the Speed and Lateral G combo boxes will contain channel names, and the Lap combo box will contain laps, and the track map window may contain a map. The 'circuit direction' indicator shows whether the lap is clockwise or counter-clockwise.

Select the Speed and Lateral G channels using the combo boxes, and select the units used to measure speed.

Select a representative lap to use as a reference. It doesn't have to be the fastest lap, but one that would be a good match for laps in the working session.

### ***The Map***

Once the reference session's Speed, Speed Unit and Lateral G traces have been selected, the track map window should show the layout of the circuit. No map is displayed for laps that are not complete circuits. If the input channels are not selected correctly, or the speed unit is incorrect, the map may look a little bizarre.

Use the Map Rotation control to the right of the map window to rotate the track map until it looks familiar. The black spot shows the location of the beacon.

When the track map appears as a mirror image of the real circuit layout, use the 'flip' checkbox to invert the Lateral G trace. BeaconFinder expects Lateral G to be positive in a left turn, to match the output of the AIM MyChron3 and MXL dash loggers. The direction of positive Lateral G may be reversed in your installation.

When more than one lap is present in the reference session, it is possible to compare the track maps for different laps. Click on the Lap combo once, then click again to keep the combo selected and hide the drop-down list. The Up and Down arrow keys can then be used to scroll through the laps in the reference session.

The program has to apply a certain amount of trickery in order to create track maps where the end point of the lap meets the start point. As a result, it does not seem reasonable to suggest that the difference in the maps between laps can accurately reflect differences in racing line (sorry!).

If the shape of the track map doesn't look quite right, use the 'map adjust' slider below the track map. This control introduces a fudge factor into the map calculation equivalent to scaling either the speed or lateral G traces. Needing to use this control to get the map to look right suggests that the logger calibration should be checked.

- For example, if the map control needs to be set to '80' to for the map to look right, this suggests that either the speed channel is under-reading by 20%, or the lateral G channel is over-reading by 20%, or some combination of the two.

If the track map still looks odd after using the 'map adjust' control, please check the calibration of your lateral G channel. For example, calibrating the logger on a sideways slope can give a constant offset that can make the map look odd!

### ***Choosing a reference lap***

For best results, choose a reference lap from the same car and driver as the working session, under similar conditions.

If the working session contains at least one good lap (IR hit at start and finish), load the same data file to the working and reference sessions.

BeaconFinder searches the corner radius in the working session for matches against the reference lap. When choosing a reference lap, it is important to be aware of the factors that will affect the quality of matches.

Different drivers in the same car, or different weather conditions may lead to variations in racing line and hence the shape of the corner radius trace.

Brake locking (front wheel sensor) and wheel spin (rear wheel sensor) affect the vehicle speed trace – which in turn affects the computation of distance traveled and corner radius.

If you don't have a reference lap from the same car – try using a reference lap from another car. There may be slight variations in lateral G and speed calibrations, but it will still be possible to extract lap times. The accuracy of the result is not likely to be as good as when using a lap from the same car.

### **If no reference lap is available**

If you don't have a reference lap at all – then you can make one!

Look at speed and lateral G data in RaceStudio2 – when multiple laps are present it should be possible to identify repeating patterns, and to determine which corner is which.

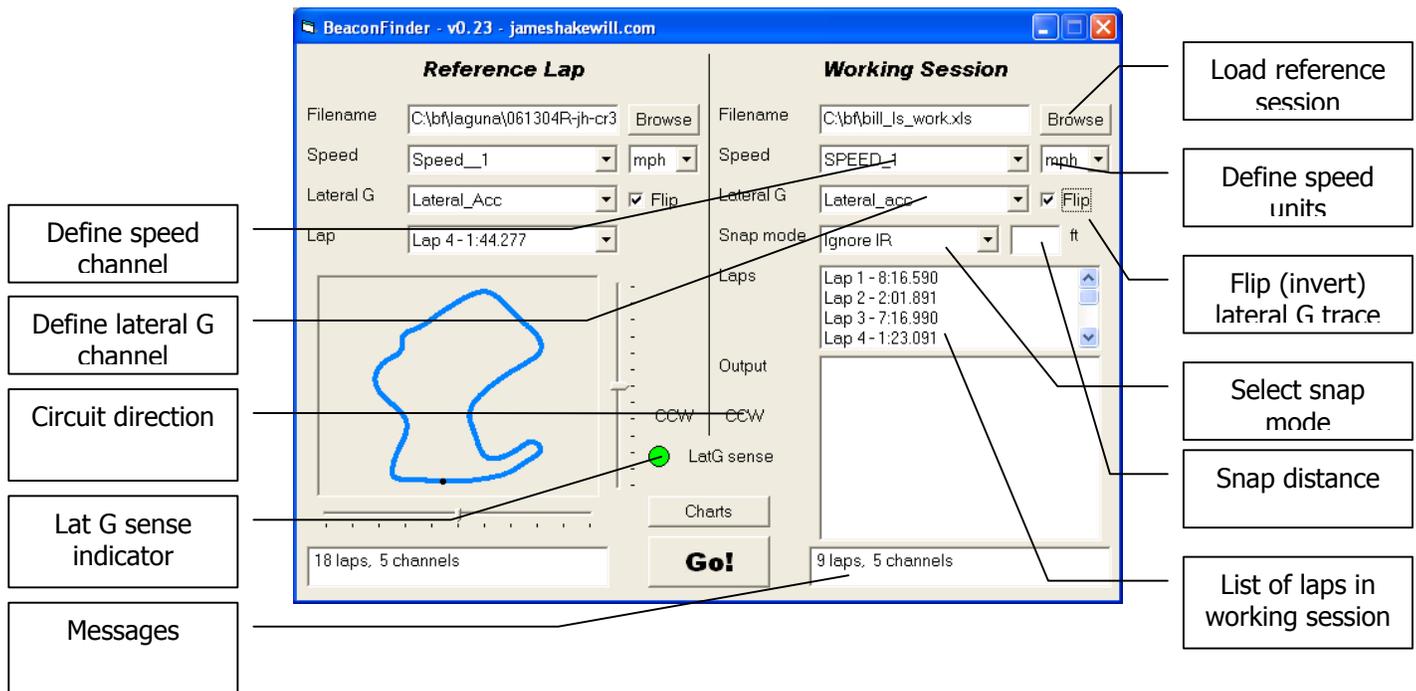
- Find a lateral-G feature related to the first corner, common in multiple laps
  - Note distance
- Move backwards some fixed distance (e.g. 300 ft) from that point
  - Note time
- Repeat for the next lap
- Insert two laps using the 'Insert lap' feature of RaceStudio2's lap manager
  - First lap – The first noted time (lap start point)
  - Second lap – The difference between the first and second noted times (lap end point)
- Export the session, and use the second inserted lap as the reference

## The Working session

To load the working session, click on the ‘browse’ button in the Working Session section of the BeaconFinder window. Select the desired file and click OK.

If the file could not be loaded, or something bad happened, a message will appear to that effect. The most likely causes of errors are:

- The file selected was not exported from AIM RaceStudio2
- The data was not exported against Distance/Time
- Something bad happened inside the program



If the file was loaded successfully, the Speed and Lateral G combo boxes will contain channel names, and the Lap combo box will contain laps. Select the Speed and Lateral G channels using the combo boxes, and select the units used to measure speed.

The ‘circuit direction’ indicator shows whether the lap is clockwise or counter-clockwise. The ‘LatG sense’ light turns red if the circuit direction of the reference and working laps are different – indicating that either the working or reference lateral G channel needs to be flipped.

### ***Snap mode***

The snap mode feature allows control over how BeaconFinder deals with lap start points that already exist in the data. When a new lap starts in the data and the vehicle is moving, this is taken to be an IR (infra-red) beacon hit.

Three options are available for snap mode:

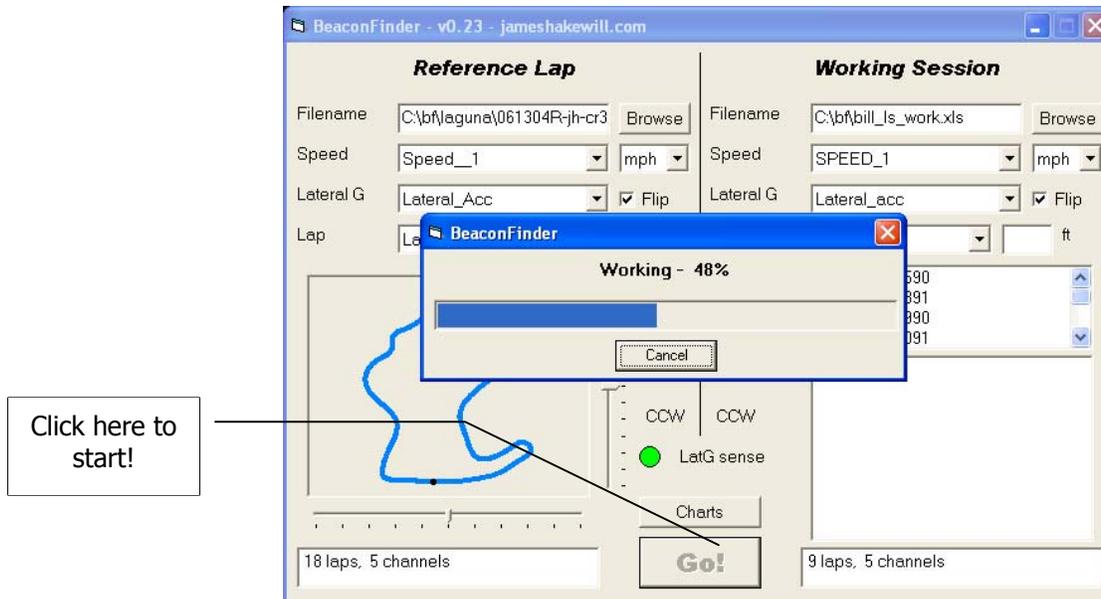
- Ignore IR (the default)
  - All lap start points from IR beacon hits are deleted and ignored
  - Lap start point from vehicle-stop are left in place
  
- Snap to IR
  - When a calculated lap start point is close to an IR beacon hit
    - Use the lap start point from the IR beacon
  - IR beacon hits found outside the specified distance are ignored
  - Snap distance is entered in the box to the right of the Snap Mode combo box
  
- Beacon Shift
  - Calculates average Beacon Shift between sessions
    - Lap start points calculated independently of IR beacon hits (like Ignore IR mode)
  - For each lap, Distance is reported between
    - Calculated lap start point and
    - IR-beacon lap start point
  - The average of the reported beacon-shifts is given

Snap to IR should only be used when you are certain that the beacon position in the reference and working laps is the same. For example, it is ideal for replacing occasional missing beacon hits – when loading the same file into both the working and reference sessions.

Beacon Shift should be used with sessions with good quality IR beacon hits on each lap. The average beacon shift should be used to shift the working session to overlay with the reference session.

## Starting calculations

To start calculations click on the “Go!” button at the bottom of the window. A progress bar will appear to show how the calculations are going.



In the present version of BeaconFinder, a large number of calculations are required to locate lap start points. The length of time required is affected by:

- Sample rate of reference lap
- Length of reference lap
- Sample rate of working session
- Length of working session

The calculation can be cancelled at any time by clicking on the ‘Cancel’ button or closing the progress bar dialog box.

## Results

When the calculations are complete, the list of output laps will appear in the 'Output' list on the right hand side of the window.

The screenshot shows the BeaconFinder v0.23 interface. The 'Reference Lap' section on the left includes fields for 'Filename', 'Speed' (Speed\_1), 'Lateral G' (Lateral\_Acc), and 'Lap' (Lap 4 - 1:44.277). The 'Working Session' section on the right includes fields for 'Filename', 'Speed' (SPEED\_1), 'Lateral G' (Lateral\_acc), and 'Snap mode' (Ignore IR). The 'Output' list in the 'Working Session' section contains the following data:

Lap	Time	Notes
Lap 1	8:16.590	(Original #1)
Lap 2	2:01.891	(Original #2)
Lap 3	7:16.990	(Original #3)
Lap 4	1:23.091	(Original #4)
Lap 5	4:20.950	
Lap 6	1:45.900	
Lap 7	1:42.900	
Lap 8	1:44.850	
Lap 9	1:43.300	

Callout boxes on the right side of the screenshot provide the following information:

- List of output laps
- Laps retained intact from working session, with original lap #
- Use scroll bar to see all the laps
- New laps created by BeaconFinder

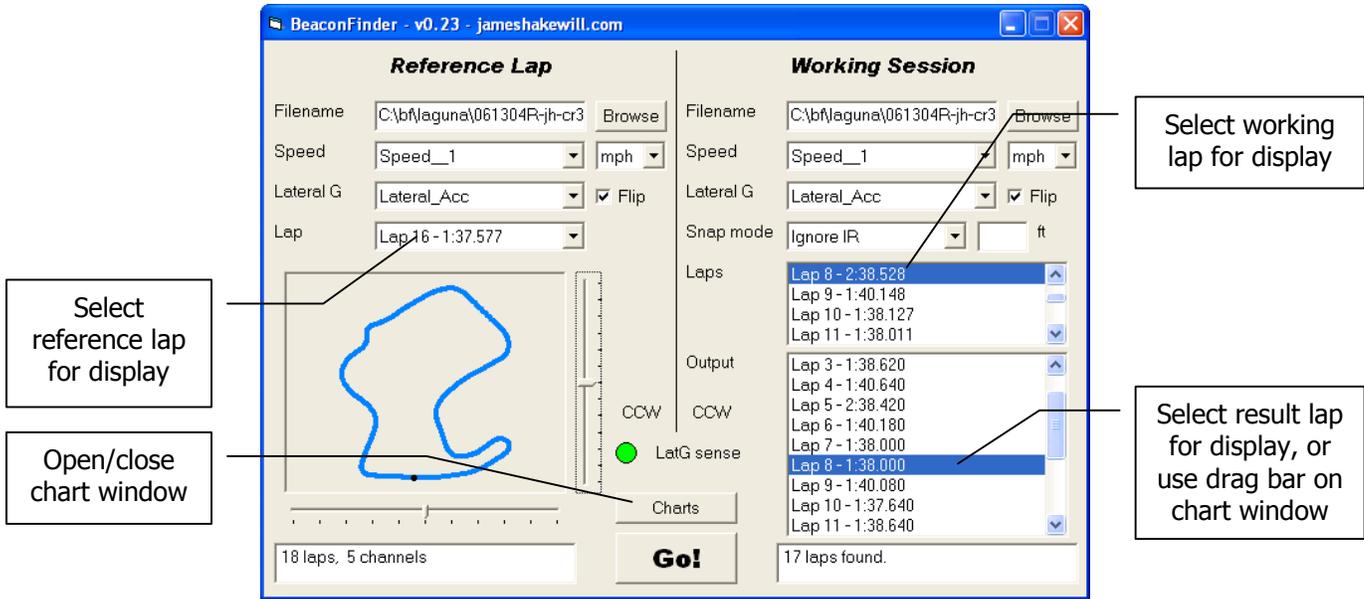
Laps that were retained intact from the working session are marked with their original lap numbers, and retain their original lap times.

All newly created laps have their lap times quantized to the sample rate of the working session – for example at 50Hz, the smallest increment of lap time is 0.02s.

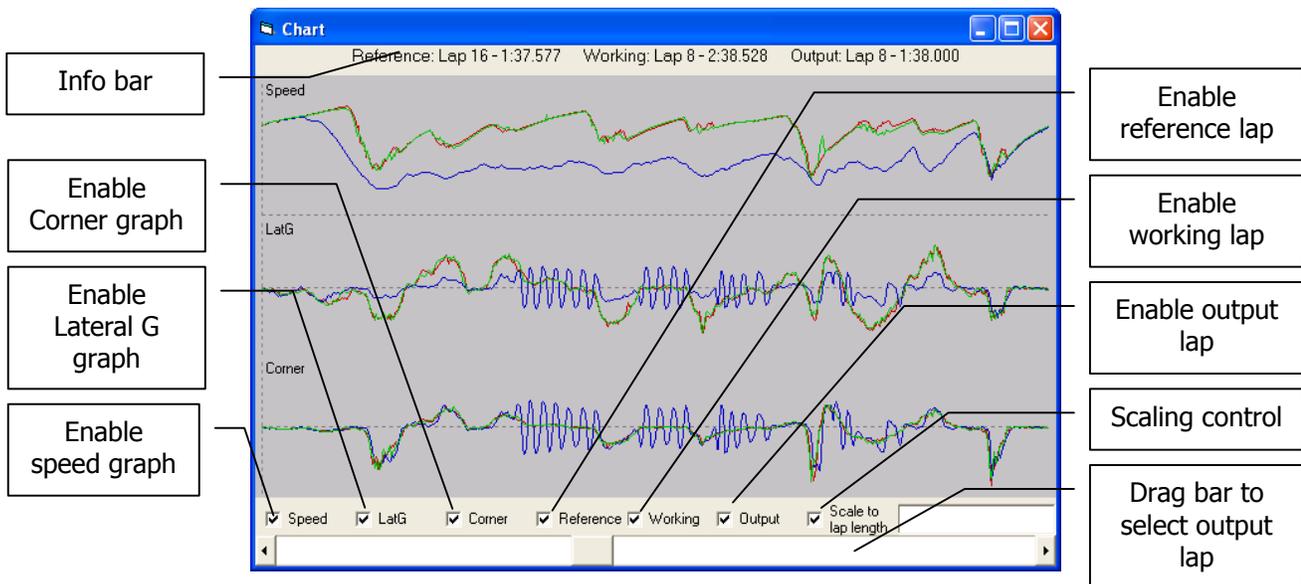
The results window will be cleared when a new calculation run is started.

## Charts

The chart window can be opened and closed by clicking the 'charts' button on the main BeaconFinder window.



Select the reference and working laps to be displayed as shown above. If an output session exists, the lap to be displayed can be selected from the list of output laps.



In the chart window, controls are provided to enable display of any combination of speed, lateral G and corner traces. Controls are also provided to enable the reference, working and output sessions.

Use the drag bar at the bottom of the screen to quickly change the output lap – click on the bar to select (it will flash), then use the left and right arrow keys to scroll through the output laps.

A useful feature is the ‘scale to lap length’ control:

- When checked (default)
  - All laps displayed are scaled to the size of the window
  - Hence each trace displayed is on a slightly different horizontal scale
  - Evens out small differences in lap lengths
  - This mode is used by RaceStudio2 when drawing charts
  
- When unchecked
  - Charts are scaled to the length of the longest lap
  - All traces are on the same horizontal scale
  - A ‘lap’ containing more than one circuit can be displayed along with the reference lap
  - Differences in lap lengths are exposed
    - When comparing data from two cars, if one car has much longer laps the another at the same track, this may indicate a problem with speed channel calibration

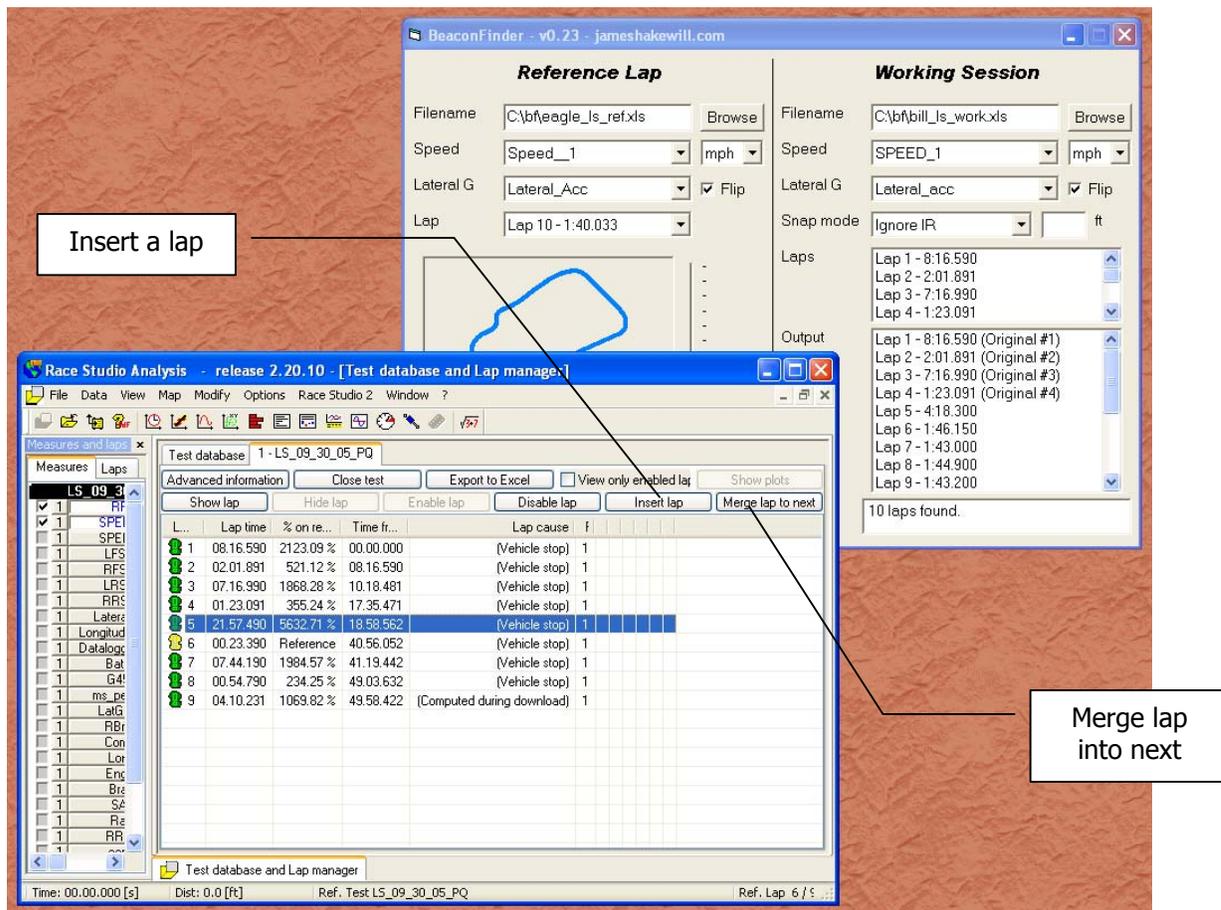
Colors in the display are as follows:

- Reference lap is Red
- Working lap is Blue
- Output lap is Green

## Editing lap times in RaceStudio2

When BeaconFinder’s calculations are complete and a list of lap times has been produced, then some manual work is required to get the lap times into RaceStudio2.

Life would be much easier if BeaconFinder could read and write RaceStudio2’s .drk format files, but it can’t!



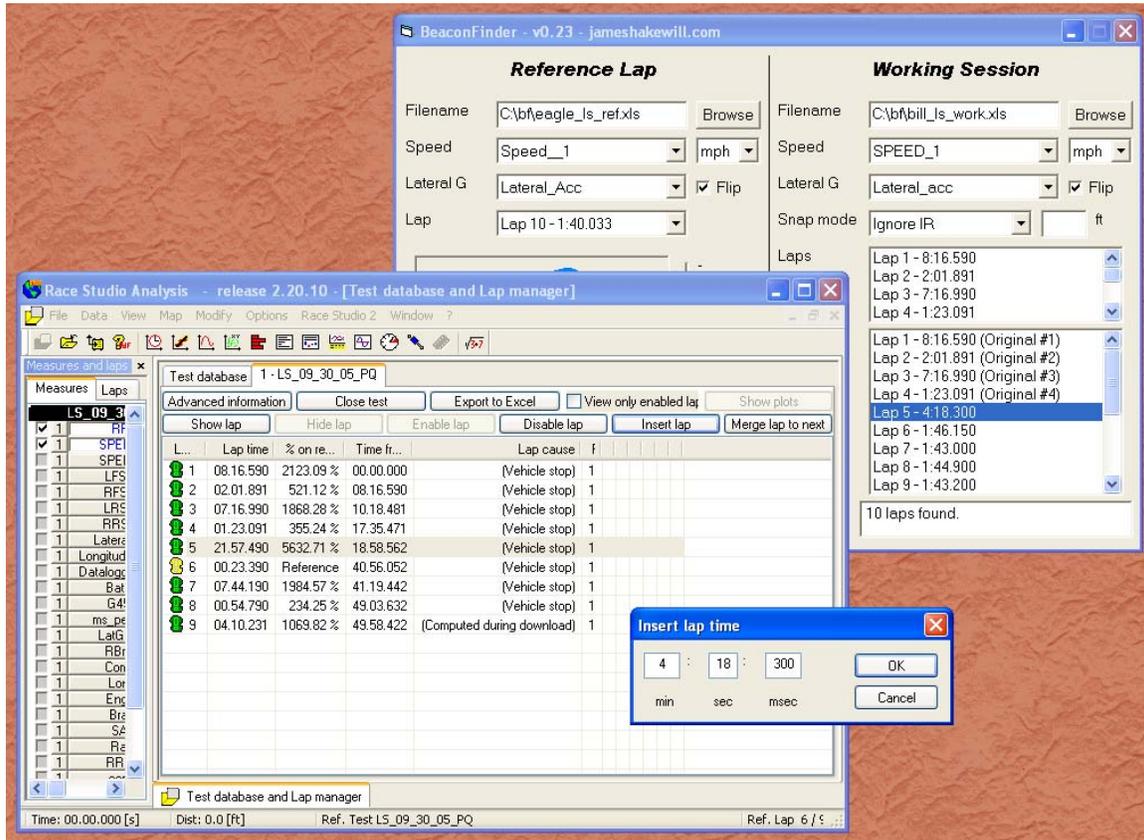
Before you do anything, make a backup of the session file you are about to edit!  
Remember that once lap times have been edited in a RaceStudio2 session you can no longer use the ‘beacon shift’ feature on the file.

Load the session in question into RaceStudio2 and select the Lap Manager screen, as shown in the picture above.

All laps should be merged together into one large lap, leaving in place any laps marked ‘original #n’ by BeaconFinder. If there were no beacon hits, you will already have one huge lap so this won’t be necessary, but when existing lap end points need to be removed (such as bogus beacon hits) it is necessary to merge laps together before breaking them apart again.

To insert laps, identify the original laps to be left in place in both RaceStudio2 and BeaconFinder.

Select the next lap (e.g. the huge lap just created by merging) and click the ‘insert lap’ button. Check with the BeaconFinder window and type in the laptime of the first lap to be inserted. Note that three digits including leading zeroes must be typed into the ‘msec’ field – 5 means .005 not .500 as you might expect.



The new lap will appear in RaceStudio2 marked ‘computed splitting a lap’.

Next, select the huge lap (which should now be smaller) and click on ‘insert lap’ to add the next lap from BeaconFinder.

If your screen allows, it is helpful to arrange the RaceStudio2 and BeaconFinder windows such that both can be seen at once.

When the second-last new lap has been inserted, the remaining part of the huge lap should have a lap time very close to the last lap shown in BeaconFinder. If not, you may have made a typing error.

Before closing the session, double-check the lap times in RaceStudio2 both in the list and by overlaying the laps in the 'plot channels vs distance' view. The manual process of transferring the lap times is tricky to do without error!

In the likely event that you do make a typing error at some point, select the incorrect lap and merge it into the next. Then merge any laps inserted after the incorrect one until you're back with a big lap. Then start again with 'insert lap'.

## **If something bad happens...**

Please let me know, since then it might get fixed!

Any problem is easier to fix if it can be reproduced. Please send an email to [beaconfinder@jameshakewill.com](mailto:beaconfinder@jameshakewill.com) with the following:

- The message (if any) that was displayed when the problem occurred
- What you did before the problem occurred
- The operating system that you're using (XP, 2000, Windows98 etc).
- The version number of BeaconFinder that is being used
- Please attach the source files that were loaded into BeaconFinder when the problem occurred!

## **Suggestions**

Please get in touch with suggestions for how to improve the features or usability of BeaconFinder, or for some other data-logging or analysis product entirely!

James Hakewill  
19<sup>th</sup> July 2007

**Quick reference**

Problem	Use Reference Lap from	Snap Mode
Occasional missing beacon hits	Working session	Snap to IR, try 50 ft
No beacon hits	Another session	Ignore IR
Hits from multiple beacons, no blockout time (short lap, long lap)	Another session	Ignore IR
Hits from multiple beacon, occasionally misses first beacon (lap lengths vary, laps do not overlay cleanly)	Another session	Ignore IR
Calculate Beacon Shift (use sessions with good quality IR beacon hits)	Another session	Beacon Shift

**Document**

Version: 1.0

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