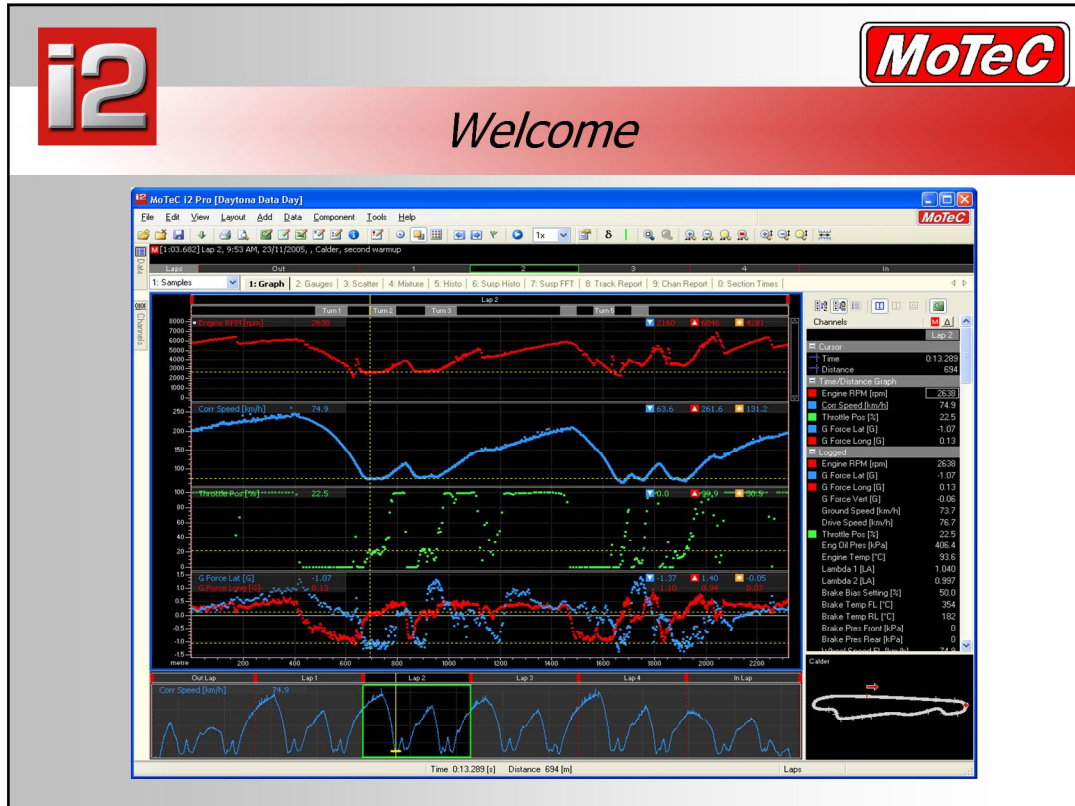# MoTeC i2 Training Seminar

Welcome

- **i2** is an all new data analysis program which represents a major step forward in the evolution of MoTeC's data analysis software. **i2 Pro** may be used to analyse data from all MoTeC data logging products with the 'Pro Analysis' option, including the ACL, ADL, ADL2 & SDL as well as MoTeC 'hundred' series ECUs that have the Pro Analysis option.

- An **i2 Standard** version is also available for products without the Pro Analysis option. This can open both Pro and Standard files as well as M4/M48 log files. M8 log files can be analysed with i2 Pro.

Software Download and Installation

- MoTeC software is available for free download from the MoTeC website at http://software.motec.com.au/release or follow the links from www.motec.com.au

Current Release Software

| i2 Standard				
i2 Pro				
Version 1.00.0366	11.7 Mb	29 Nov 05	US Server	AU Server
Interpreter				
Version 1-30-0009 (German)	5.0 Mb	01 Dec 04	US Server	AU Server
Version 1-30-0009 (English)	5.0 Mb	01 Dec 04	US Server	AU Server
Version 1-30-0009 (French)	5.0 Mb	01 Dec 04	US Server	AU Server
ADL Dash Manager				
Version 320P3	5.4 Mb	31 Mar 06	US Server	AU Server
ADL2 Dash Manager				
Version 420S2	5.2 Mb	24 Oct 05	US Server	AU Server
Sport Dash Manager				
Version 120F2	3.3 Mb	24 Oct 05	US Server	AU Server

- While a software and resource CD is included with MoTeC products, as the software is regularly updated, it will become necessary to download the latest software from the MoTeC website. Go to www.motec.com.au and follow the links or go to http://software.motec.com.au/release

- Next to each software item are two links. The first "**US Server**" is intended for customers in the Americas, while "**AU Server**" is for local customers. If there is a problem with one, then the other can be used.

- To download software, click on the link and a dialog will appear asking if you would like to open the file or save it to your computer.

- Choose 'Save' and a 'Save As' file dialog will then appear. Save the file to a location on your PC – the desktop is suitable. The file will then begin to download. The time taken for this can vary widely and will depend on the speed of the connection to the internet.

- Once the file has been downloaded, it needs to be run to install the software. Find the program (exe file) in the location it was downloaded to and double-click on it to run the installation.

- To be informed of the latest software release you can join the MoTeC software announce mailing list by sending an email to announce-subscribe@motec.com.au

Standard vs Pro

Standard Logging
- **Single overlay lap**
- **Simple maths functions**
  - **Corrected speed / distance**
  - **Filter, scale and offset**
  - **+ - * /**
- **15 Worksheets**
- **5 time/distance graphs**
- **10 Channels per graph**
- **5 Outing graphs**
- **2 Histograms**
- **1 Scatter plot**
- **1 Mixture map**
- **1 Track Report**
- **Section Times**

Pro Analysis
- **Multiple overlay laps**
- **Advanced mathematics**
  - **user maths**
  - **global maths**
  - **flexible Expressions**
- **Unlimited display components**
- **Unlimited workbooks**
- **Unlimited worksheets**
- **User definable track sections/sectors**
- **Lap Reports**
- **Statistics zoom**
- **Suspension Analysis**
- **Video**
- **Multiple projects**

▪ This list shows some of the major differences between the two software versions.

▪ The pro analysis upgrade can be purchased at any time allowing you to use the more powerful software when the need arises. This can even be done at the race track, you need only contact your dealer, and they can supply the password to upgrade your specific device.

▪ Standard logging has been designed with the intention that it be suitable for teams up to around middle level motor sport. Pro Analysis has all the features from Standard, but added on top of that are extra features that have been requested by professional race teams world wide, and is expected to be used by those in middle to upper levels of motor sport.
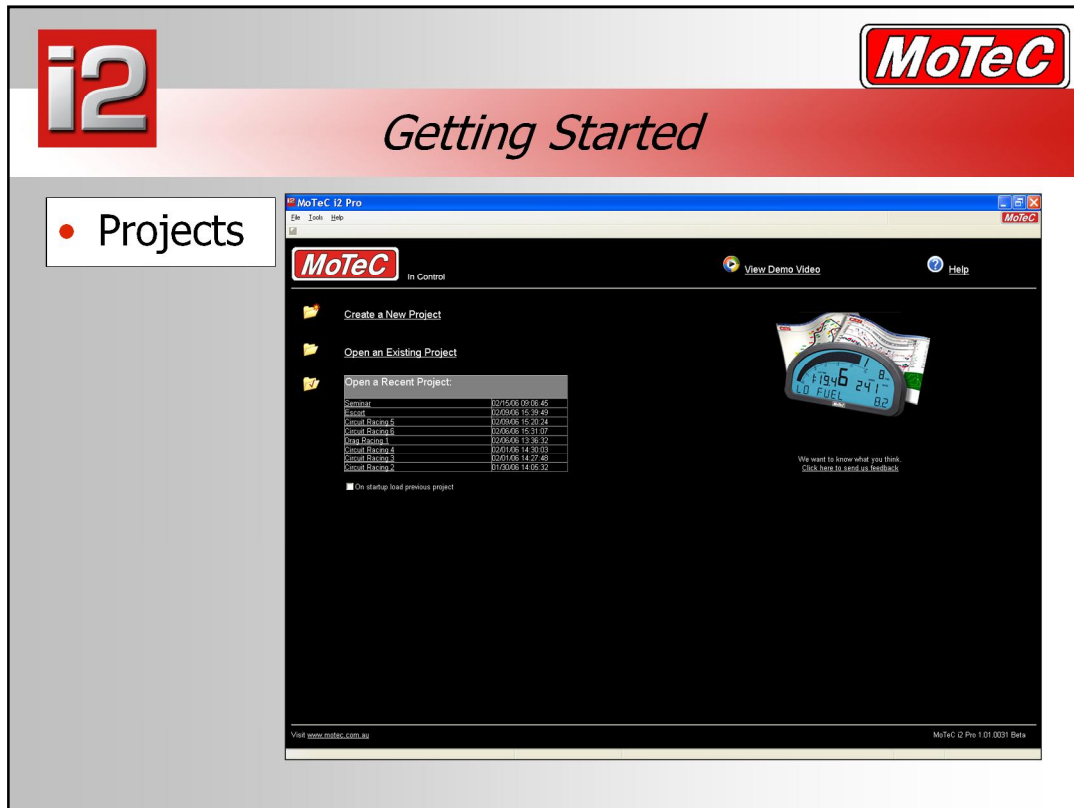
- A Project stores the *i2* program settings, screen layouts, math calculations etc used for analysis. Projects can be defined per vehicle, by type of racing, etc. A user can create as many projects as they wish each with different settings. New projects can be created or existing projects opened from the File | Projects menu or from the *i2* start up page. Any log file can be opened from within a project, so a project doesn't restrict what information can be analysed.

- The first time that *i2* is run the user is prompted to create a Project. Follow the prompts of the New Project wizard to create the first project.

- When opening *i2* standard for the first time you will be presented with the choice of 4 projects Circuit, Drag, Rally and Engine. If you click on the box "load previous project", on subsequent program starts it will take you straight into your graph screens, ready for you to open your data.
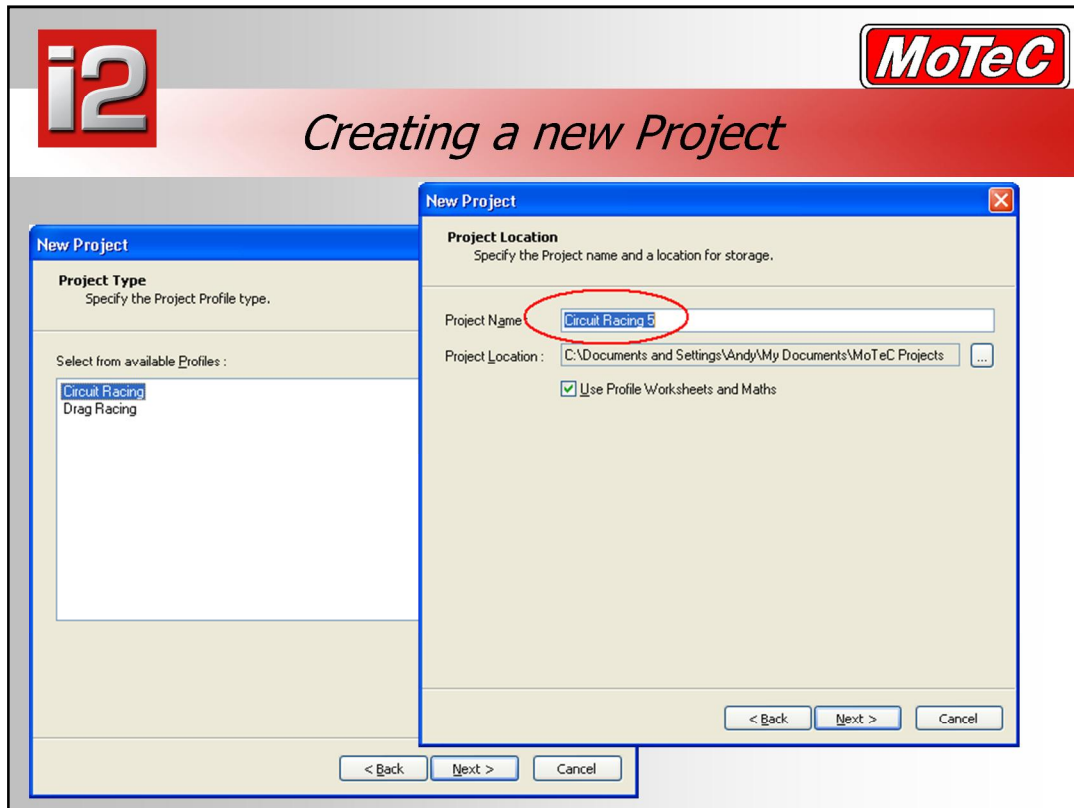
Creating a new Project

- **Project Type**: there are 4 types of project available; Circuit, Drag, Rally and Engine. The number of types may be expanded in future releases. The project type determines the default math settings and initial workbook and worksheet setups.

- **Project Location**: Enter a descriptive project name. This will be used as the folder name under which the project is stored. By default, projects are created in the current users 'My Documents' folder under 'My Documents\MoTeC Projects\Project_Name\' This can be changed by clicking on the button next to the Project Location and browsing to the destination folder. Renaming the folder will rename the project.

  – Profile Worksheets and Maths are included if the box is checked, otherwise the project is blank with no predefined maths or screen layouts.

- **Project Summary**: After checking the project summary, click on Finish to close the wizard and begin using *i2*.

The entire project folder can be copied from one PC to another and some of the components can also be copied. The project folder and its directory structure contains individual files for channel maths, setup sheets, track maps etc.
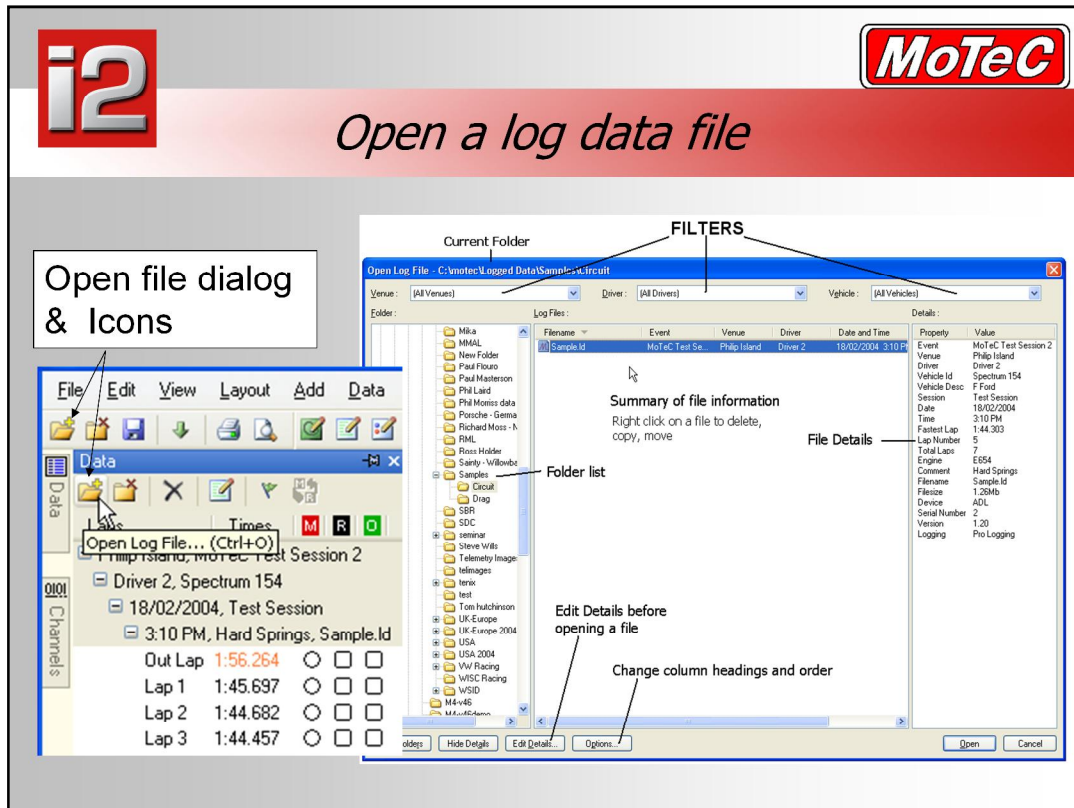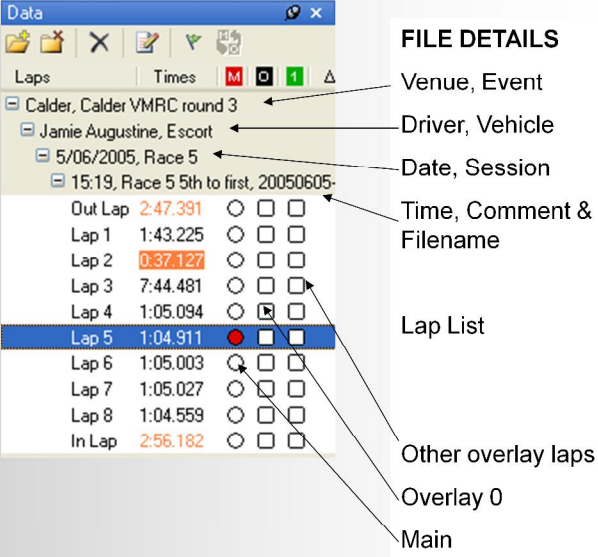
Open Log File dialogue

- A file can be opened by going to the 'File' menu and selecting 'Open Log File', by using the keyboard shortcut 'Ctrl+O' or by clicking on the Open Log File icon on the toolbar.

- On the left is a folder view with the currently open folder highlighted in grey, the folder name is also shown at the top of the window. Full details of the currently selected file are shown in the pane on the right.

- Files shown can be filtered by the Venue, Driver name or Vehicle details by selecting one or more of these from the drop down lists.

- Files can be sorted by the columns shown at the top of the centre pane by clicking the heading once – and again to reverse the order.

- Columns shown and their order can be selected from a list by clicking on the 'Options' button or by right-clicking on the row of headings to a list of selectable headings.

- Select the required file and click on 'Open'.

- Multiple files can be open at once allowing data to be selected from a number of sources - when a file is opened, previously opened files remain 'open'. Files can be closed individually or as a group.

1. *You should now open three files.*
   They can be found in "C:\MOTEC\LOGGED DATA\SEMINAR"
2. *Open file Calder VMRC round 3, 5-6-2005 at 3:19*   *(Race 5, 5th to first)*
3. *Open file Daytona Testing, 23-11-2005 at 9:35*   *(1st warm up)*
4. *Open file i2 data day, 23-11-2005 at 9:53*   *(second warmup)*

Data Window

- Lap Selection
- Main
- Overlay
- Other Overlay Laps

FILE DETAILS
- Venue, Event
- Driver, Vehicle
- Date, Session
- Time, Comment & Filename
- Lap List
- Other overlay laps
- Overlay 0
- Main

Data Window

- Press F8 to go into the data window.

- This window lists files that are currently 'open' that you may choose to view. You can open as many files as you like from any folder on your computer. Once one or more files have been opened they will appear listed down vertically along with some file details as shown above.

- Use 'R' to select the first overlay lap, and 'O' for an additional overlay. Otherwise press 'M' or 'enter' to select the Main lap. The fastest lap in a session is highlighted in orange. Using the F4 key toggles the overlay lap on and off. F3 toggles variance.

- One lap is chosen as the '**Main**' lap, this is indicated by a red dot in the circle next to the lap time. The next column across is for the '**Overlay 0**' lap. This is actually the first overlay lap (displayed on those components that only support a single overlay) and is also used for the variance calculation. The third column is for additional '**Overlay**' laps that are displayed on graphs and in channel reports. The Main, Overlay 0 and Overlay laps can all be from different files or sessions. The trace colour of an overlay lap can be changed by clicking on its label in the title bar above the main display.
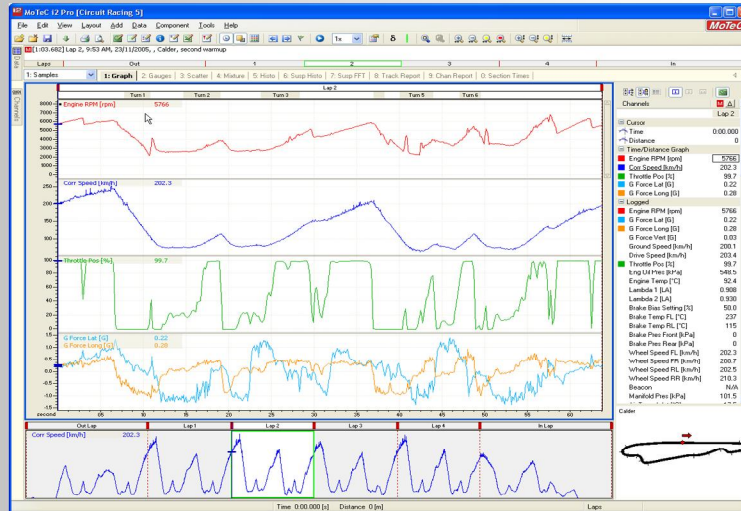
Workbooks and Worksheets

- Worksheets are used to contain the screen layouts, ie: where the data is actually displayed. Each worksheet is completely configurable and may contain a number of different components such as Graphs, Histograms, Gauges etc. These can all be mixed together in any one worksheet.

- Workbooks are used to group a number of worksheets. This allows a large number of worksheets to be defined and organised into categories to suit the users requirements. A project can contain any number of workbooks which in turn can contain any number of worksheets.

- Above is the first sample worksheet included with a Circuit Racing project. It contains 2 graphs, one showing multiple channels over a single lap and the other, an outing graph, showing the speed channel for the entire session. On the right is a list of available channels and their value at the cursor position. Below that is a track map of the circuit. If the project has not opened a file from this venue before *i2* will attempt to create a track map from the currently selected lap.

- Note: an Outing graph is one that always shows data from the whole session, it cannot be zoomed

1. ***Select lap 2 (1:03.682) from the Calder, i2 data day file from 9:53am***
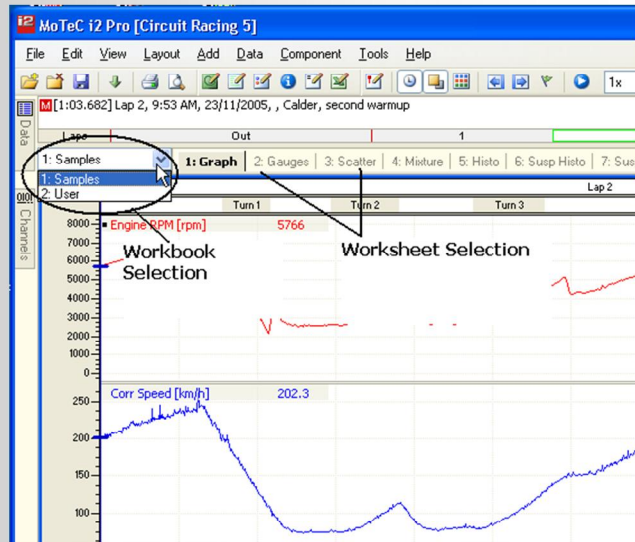
Selecting a Worksheet

- To select a worksheet use the mouse or press F7 to activate the Select Worksheet dialog or press the number key corresponding that is shown on the worksheet tab.

Keyboard shortcuts

- Worksheets may be selected by pressing the corresponding number key (0…9)

- Workbooks may be selected by pressing the Ctrl key plus the Corresponding number key (Ctrl+0…9)

- A Circuit Racing project comes with 8 pre-defined workbooks, each with a number of pre-defined worksheets. ie: there are 10 pre-defined worksheets in the 'Sample' workbook, several others such as 'Driver', 'Engine, 'suspension, etc. and one blank worksheet in the 'User' workbook. A Drag Racing project currently comes with 8 pre-defined worksheets in the 'Sample' workbook and one blank worksheet in the 'User' workbook.

1. *Select the workbook called "SAMPLES"*
2. *Select the worksheet called "Gauges" by clicking the label*
3. *Press the key '1' to select the "Graph" worksheet again*
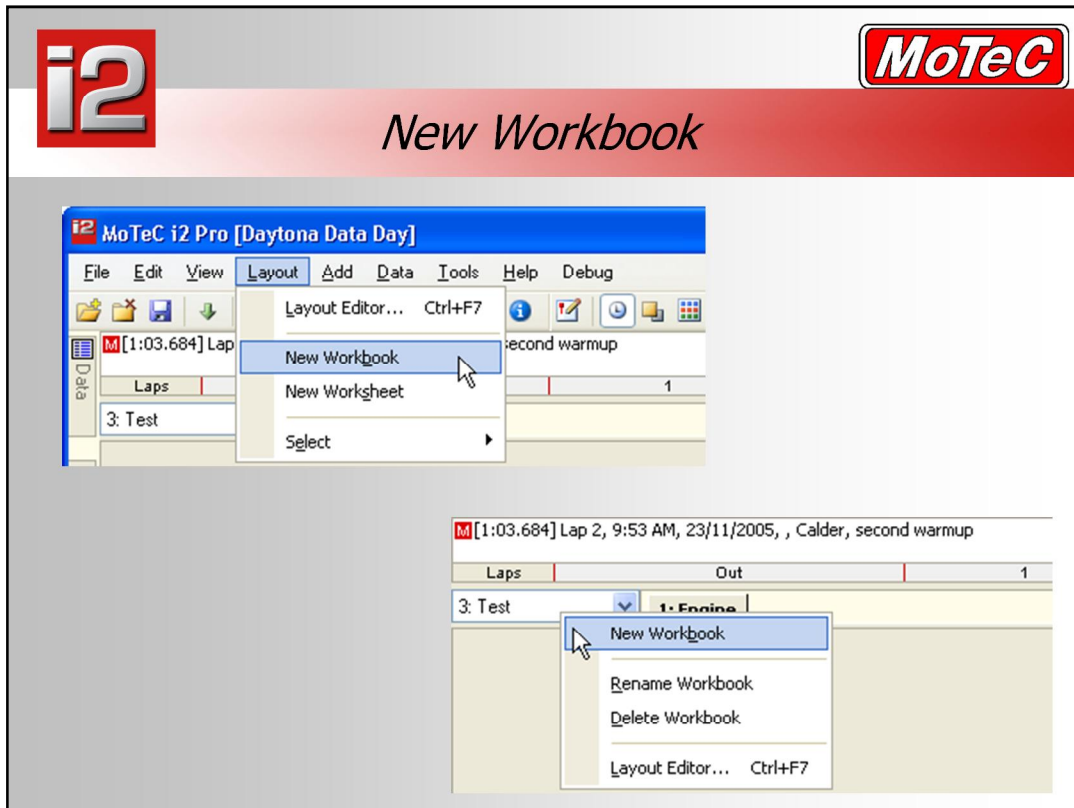
New Workbook

Creating a new Workbook

- To add a new workbook, go to the 'Layout' menu and select 'New Workbook'. Or this can be done from the Layout Editor (menu 'Layout – Layout Editor', shortcut key 'Ctrl+F7' then 'Add Workbook') or right-click on the Workbook list and select 'New Workbook'.

- You will be prompted to enter a name. To rename a workbook, right click on the drop down list and choose 'Rename' or use the Layout Manager.
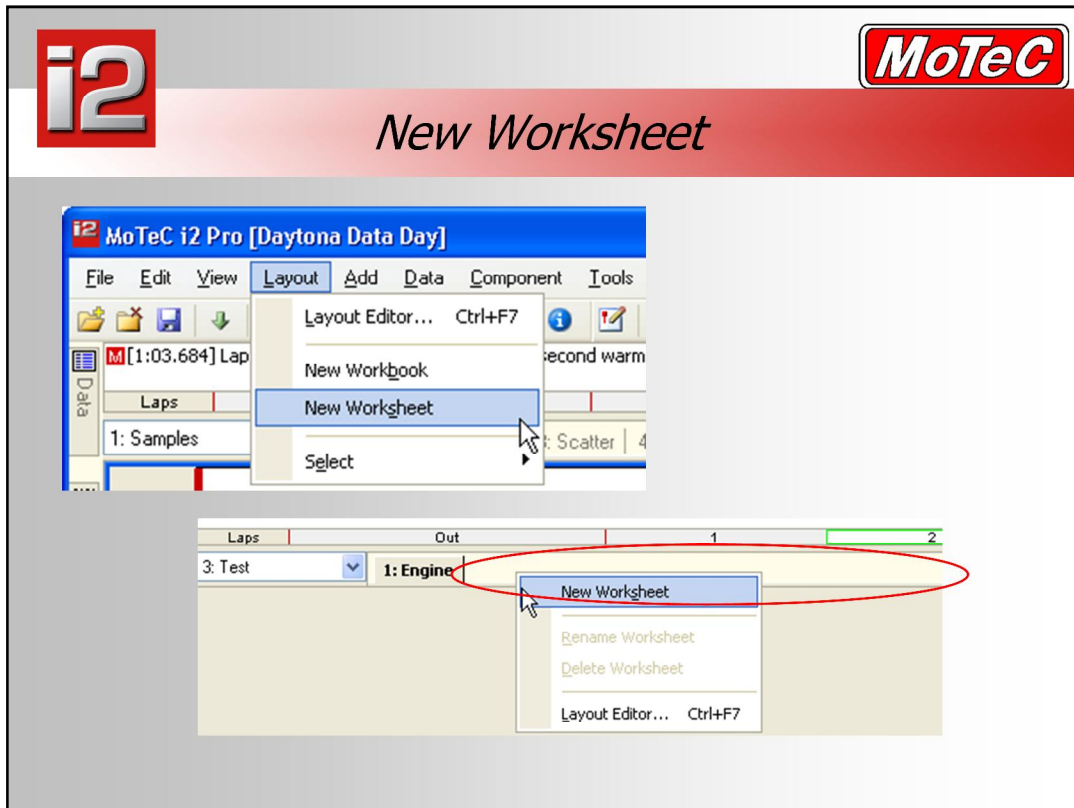
Creating a new Worksheet

▪ To add a new worksheet, go to the 'Layout' menu and select 'New Worksheet'. Or this can be done from the Layout Editor (menu 'Layout – Layout Editor', shortcut key 'Ctrl+F7' then 'Add Worksheet') or right-click anywhere on the Worksheet tabs area and select 'New Worksheet'.

▪ You will be prompted to enter a name. To rename a worksheet, right click on the tab and choose 'Rename' or use the Layout Manager.

- With a new worksheet now open you are still unable to view any data until a component has been added. Right Click any where within the blank new worksheet and a list of available components will appear. Or use the 'Layout' menu to select a new display component.

- When adding any new component, initially the software presents the relevant components properties dialog box. This allows the user to organise the component with the desired channels to view and the format they are to appear. The user can access the properties menu for the currently active component at anytime by pressing the F5 key.
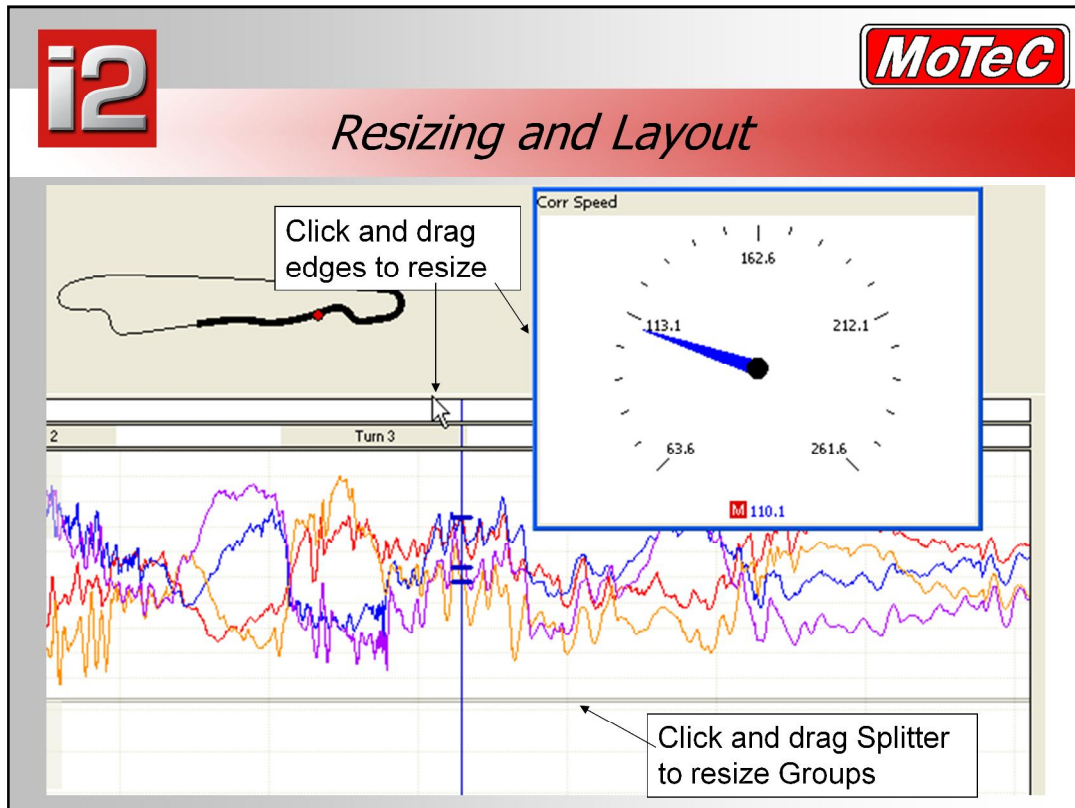
- When modifying your layout, you can examine active component properties.
- Resize components by dragging edges
- Shift + Click to move, or hold mouse over grey bar at the top of each component – the mouse cursor will change to a symbol of 4 arrows.

- Add Track Map (T)
- Transparent Track Map (Ctrl+Shift+T)

- *i2 Standard*: Once a series of worksheets has been created you can lock it by clicking on the "Lock Layout" command under the Layout menu.
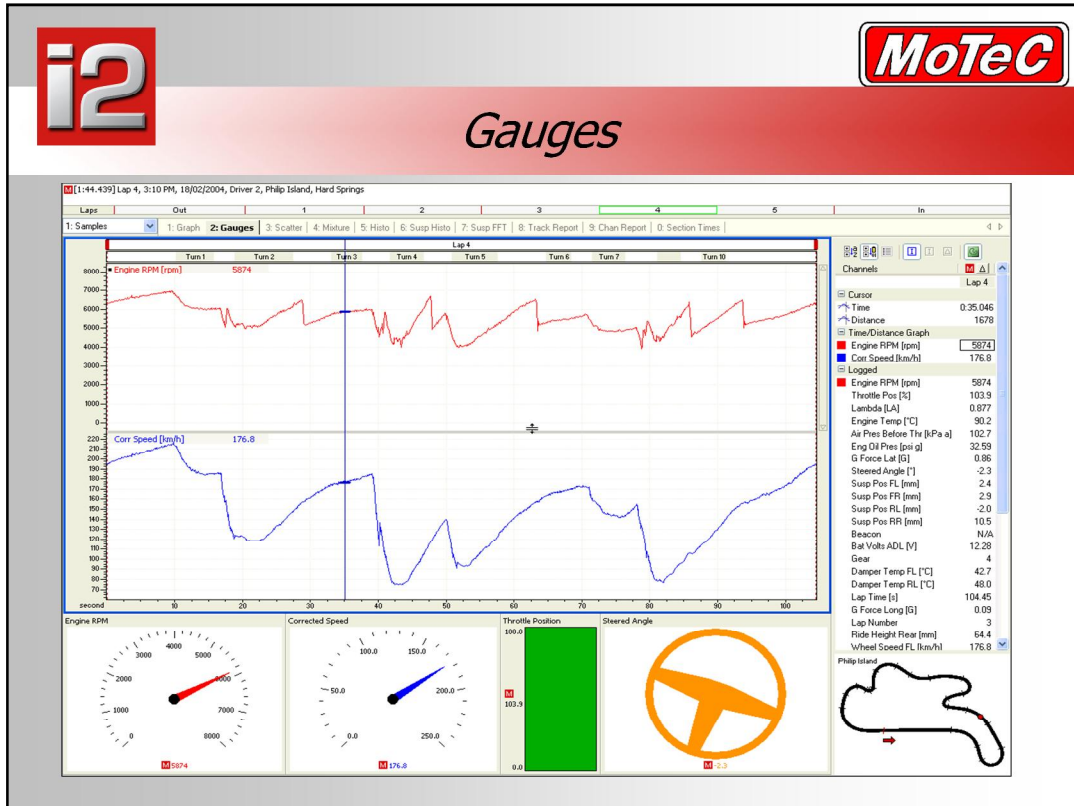
- This worksheet includes a graph as well as a selection of gauges. Gauges are most commonly used when playing back log data. The shortcut key 'A' is used to toggle the animation on/off. The playback rate can be selected from the drop down list in the middle of the toolbar.

- The gauges are linked to show the channel value at the current cursor position. This can be moved using the shortcut keys, or by clicking and dragging the cursor along the graph. In its function as a gauge the graph acts as a 'chart recorder' with the cursor moving rather than the graph scrolling across the page.

- To reorganise the layout in *i2 Standard*, the "unlock layout" box must be unchecked under the Layout Menu. It is also possible to copy and paste components when you are setting up screen layouts.

1. *Right click on the steered angle gauge*
2. *Choose the delete component option.*
3. *Right click in the spare space and choose "Add", "Gauge" and "Steering Wheel"*
4. *Select the channel to display by selecting the button to the right off the channel box*
5. *Type in steer and double click on "STEERED ANGLE" then select "OK".*
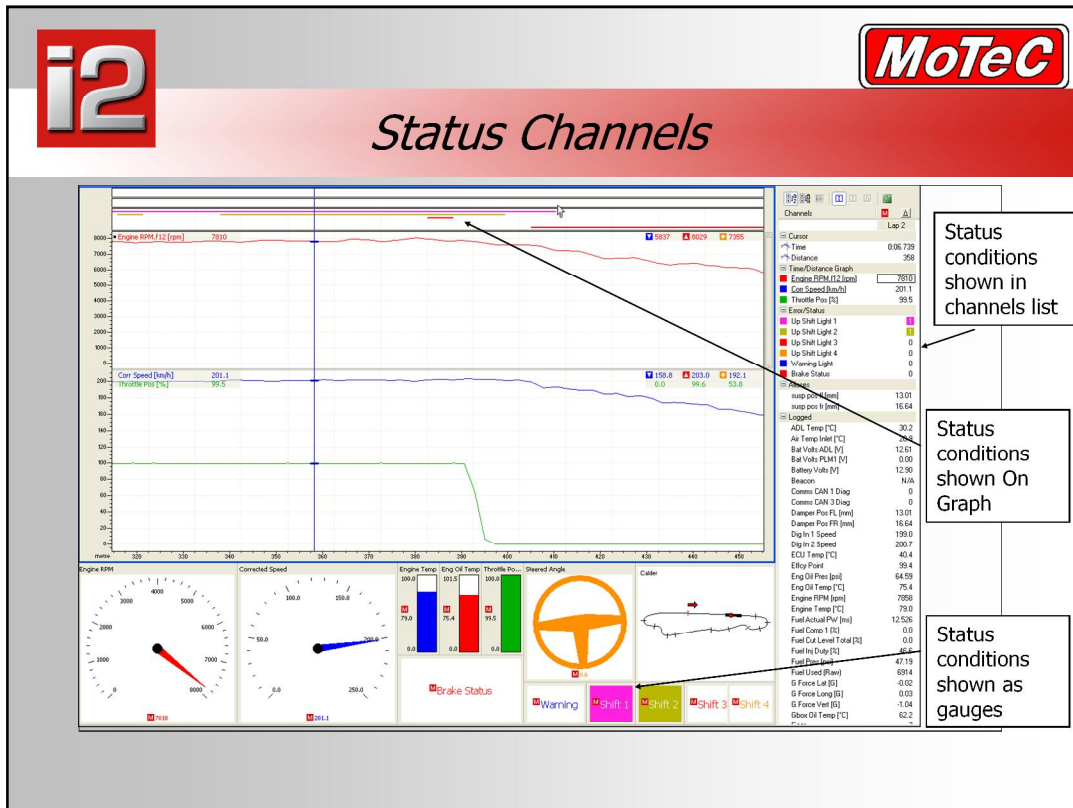
Status Channels

- Status channels are used within data logging to indicate when an on/off condition has occurred. Examples of this include a brake switch, shift lights, alarm/warning light, alarm acknowledge button, full throttle switch, clutch switch, nitrous activate and more. It is useful to see this information in the context of the rest of the data, knowing just where on the straight the nitrous is being activated, and what that is doing to your ignition timing, air fuel ratio, and ground speed.

- By pressing "E" you can turn the status conditions on and off viewing them only as required.

Add Time / Distance Graph
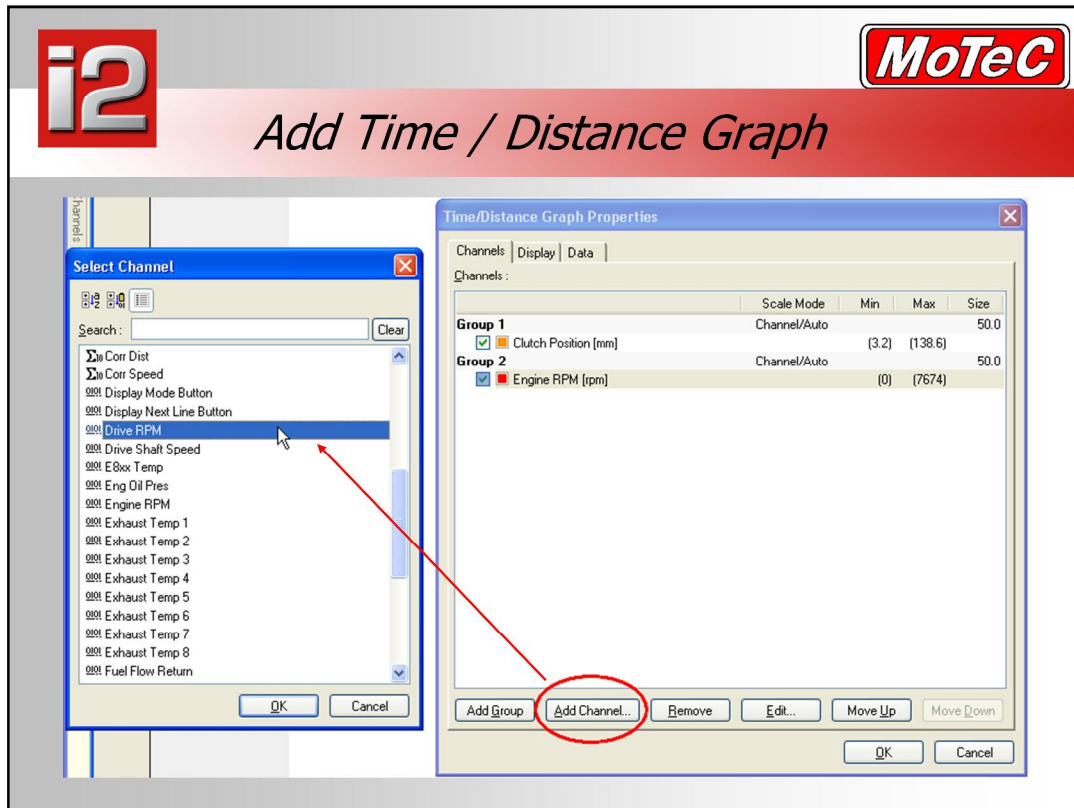
Time / Distance Graph

- Select 'Add – Time Distance Graph' from the menu bar.
  An empty graph will now appear onto which we can add channels, along with the Properties window for that graph. Even though we have added only one time/distance graph, we can add any number of channels onto this graph by clicking on 'Add Channel', then selecting channels (one at a time) from the list.

- Channels are divided into 'Groups' according to channel units. It is possible to move channels from one group to another by selecting a channel then using the 'Move Up' and 'Move Down' buttons.

- When adding multiple components, they can overlap, so resizing may be required.
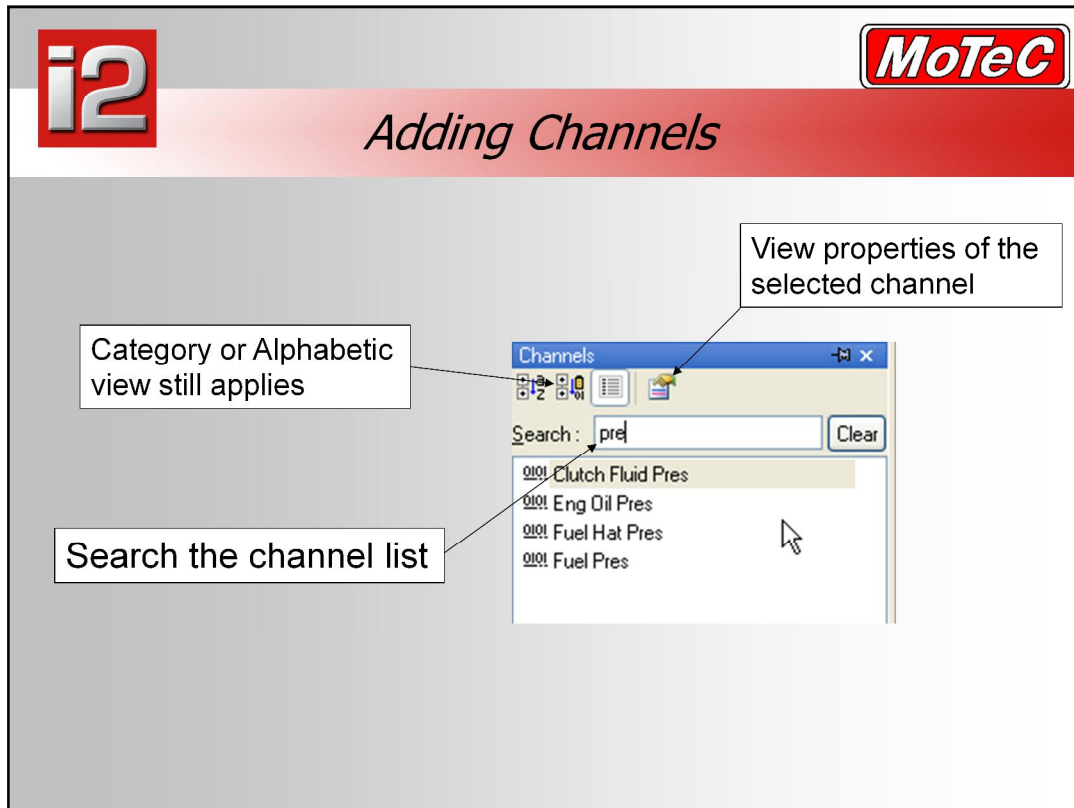
- Press 'C' to open the Channel list flyout. Double click on a channel to add it to the display component that currently has focus.

- Or, press 'Tab' to go into the channel list, arrow up and down then press 'Enter' to add a channel. Enter part or all of a channel name into the box at the top of the list to search.

- You will find that some channels are grouped together, while others remain on their own. The time/distance graph that we have added is being divided into "Groups". Each Group can have one or more channels on it. If we add channels that have the same units they will be placed on the same group, channels with different units are given a new group.

- It is possible to change the default behaviour and arranged channels according to how you want them in each case. This is done by accessing the Properties for the time/distance graph. Or hold down the 'Ctrl' key when clicking on a channel in the list to force the channel into a new Group (ie: a separate graph)

1. *Click on the group containing corrected speed to set the focus to that panel*

2. *Press the C button to bring up the channel flyout*

3. *Type "speed" into the search bar*

4. *Double click on the drive speed trace*

5. *Click back into the corrected speed group to hide the channel flyout.*

Channels Window

- Category Alphabetic Order
- Category Logged Order

- Alphabetic List

- Channel Properties
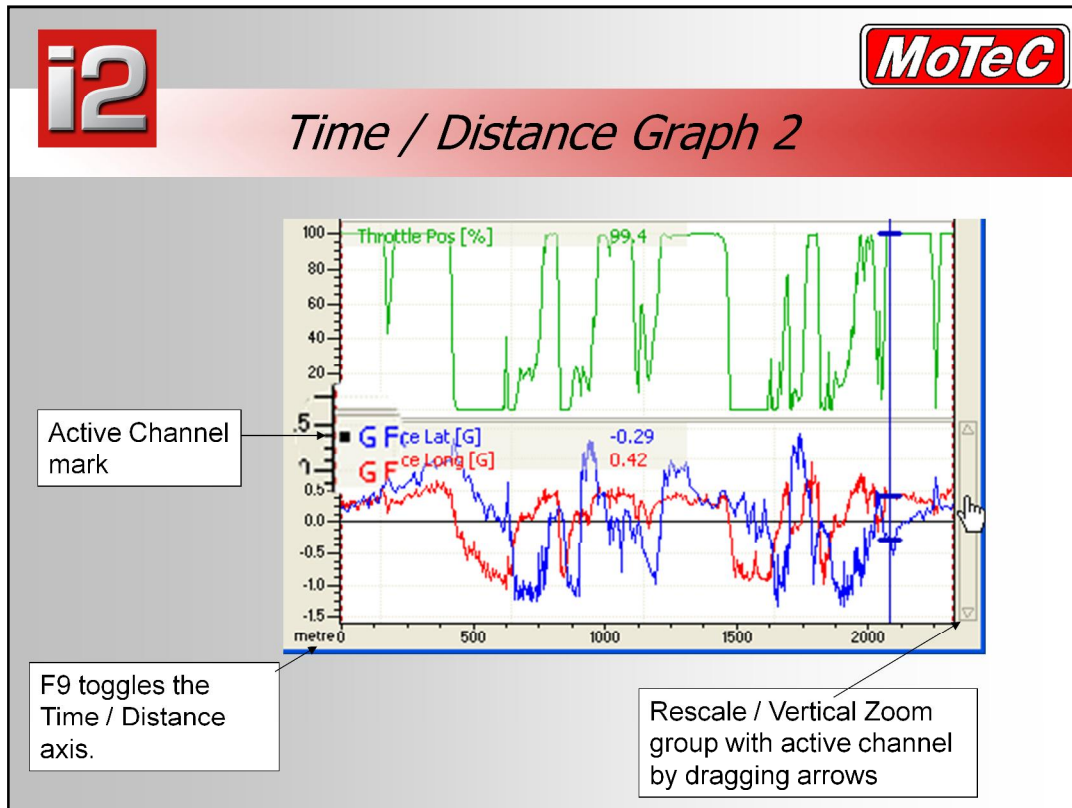
- Search Box
- Categories
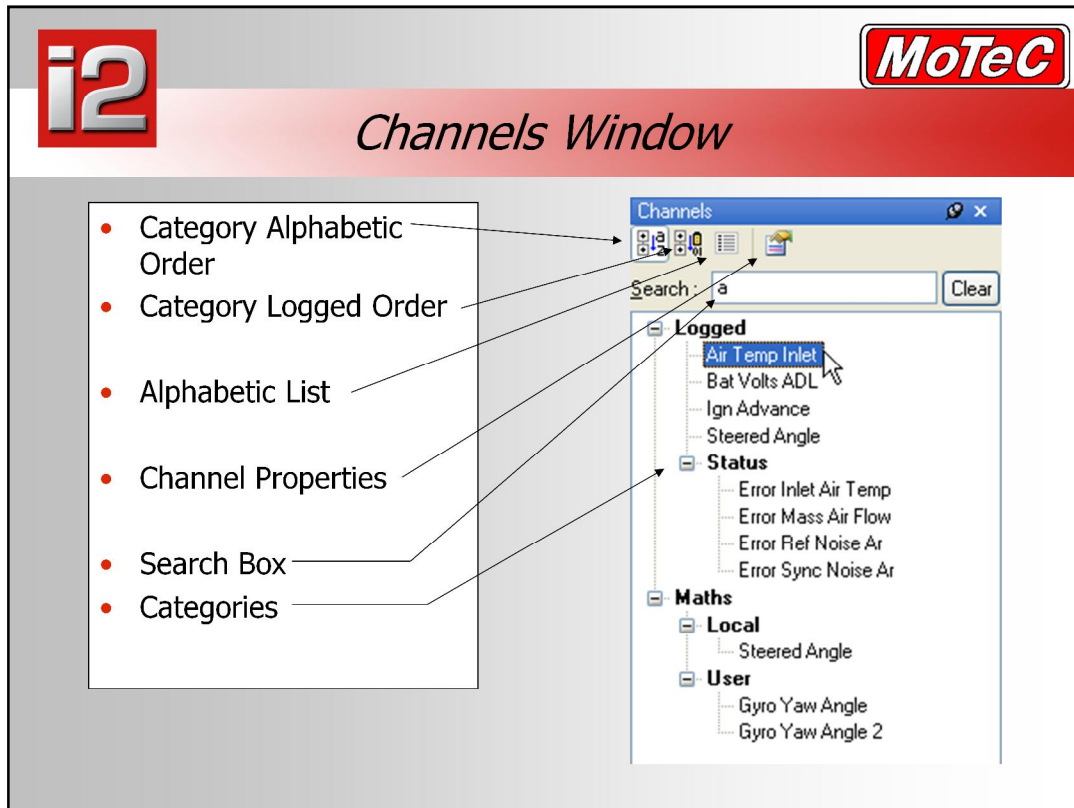
- The Channels window is used to add channels to the display component that currently has focus.

- The screen is made up of many components, a gauge is one, the time distance graph is another, an outing graph is another. The component with focus is the one with the highlight box around it.

- The list can be displayed in categories: logged channels, status channels and various maths. Or they can be displayed as a combined (alphabetic) list.

- The list of channels displayed can be narrowed down by typing the first few letters of one or more words of the channel name into the search box to make finding the required channel easier.

- To add a channel to a component double click on the desired channel or drag the channel onto the component or highlight the required channel in the list and press the Enter key.

- **Note:** Hold down the Ctrl key while double clicking on the channel or press Ctrl+Enter to add the channel to a new group on a graph rather than on an existing group with like units.

Time / Distance Graph 1
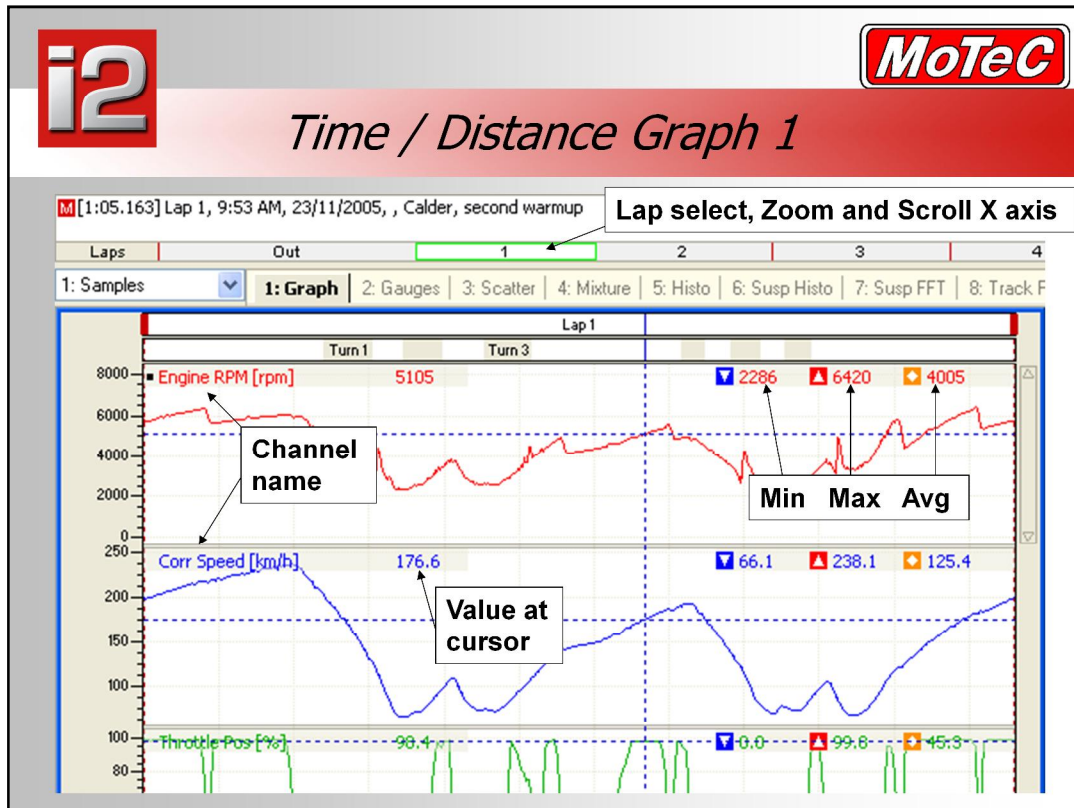
- The first sample worksheet includes 2 graphs. The top graph displays a single lap of data of 5 channels in four groups. The lower graph shows the Corrected Speed channel over the entire session. The cursors on the 2 graphs are linked, and the currently selected lap is highlighted in a green rectangle on the second outing graph.

- Lap selection bar: grab to scroll through laps, double click to select a lap, grab edges to zoom in/out

1. *Select laps by double clicking on the lap numbers, or clicking on a lap number in the data flyout*
2. *Combined graph "overlapped" – Press 'G' to show combined, then G to go back*
3. *To view the min max and average values for the on screen data – Press 'M'*
4. *View whole Outing – 'F2'. It can also be seen that the Main lap has a white background, while the other laps now have a grey background.*
5. *View single lap – Press 'W'*
6. *Zoom in and out using the up and down keys, or with the mouse scroll wheel*

Time / Distance Graph 2

Active Channel mark

F9 toggles the Time / Distance axis.

Rescale / Vertical Zoom group with active channel by dragging arrows

Time / Distance Axis

- The graph may operate in time or distance mode – the F9 key toggles the horizontal axis between time and distance. The mode is remembered for each worksheet and all components on the worksheet use the same mode.

- The graph uses the corrected distance (Corr Dist) channel to determine the distance for the axis when in distance mode. If the Corrected Distance channel cannot be calculated then the graph will not display data in distance mode. Note that the Corrected Distance calculation normally requires that the Corrected Speed calculation is working.
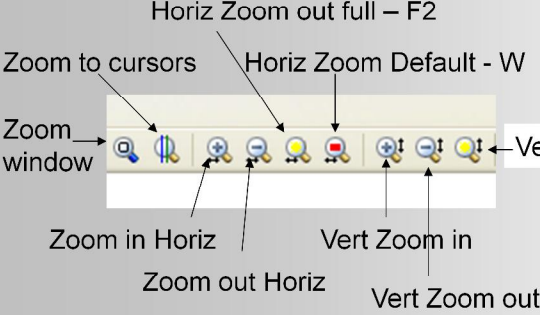
Active Channel

- Each graph has an active channel. A square next to the channel name indicates which is the active channel. The active channel can be selected by clicking on the channel label or by using the PgUp & PgDn keys.

- This is required for operations that are initiated via keyboard shortcuts. For example the shortcuts from the active channel menu will operate on the active channel. (eg Ctrl+Shift+F to filter the channel).

- Also when vertical zoom or vertical pan are used via the keyboard they apply to the panel containing the active channel.

- The active channel is also used when showing information on a particular channel – for example the datum cursor measurements that are shown in the values window are for the active channel.

1. **Press Page up and down to change channel selection.**
2. **Use the rescale / vertical zoom to horizontally zoom the data**
3. **Press F9 to change from time mode to distance mode and back again.**

Zoom Functions

- Mouse scroll
- Keyboard shortcuts
- Scroll bars
- Zoom Icons

Horizontal Zoom

- Zoom in & Out is normally performed using the Up & Down arrow keys to zoom around the cursor, or by dragging the ends of the horizontal scroll bar. The wheel on a mouse will also scroll in/out around the cursor. Place the pointer, double click and drag, then click again to zoom to the selected level.

- The W key is used to return to the default zoom level, which in the case of lap mode is a single lap. Note that if the cursor is placed on a lap other than the current main lap then the main lap will be changed to the lap that the cursor is in when W is pressed.

- The F2 key is used to zoom "Full Out" and show the entire file.

Horizontal Pan

- Horizontal pan is performed by dragging the horizontal axis or by dragging the horizontal scroll bar or using the Shift+Left or Shift+Right Arrow keys or the F & B keys (Forward & Back)

Vertical Zoom

- Vertical zoom is performed on the panel for the active channel and can be performed using the Alt+Up or Alt+Down Arrow keys, or by dragging the ends of the vertical scroll bar.

Vertical Pan

- Vertical pan is performed using the Shift+Up or Shift +Down Arrow keys, or by dragging the vertical scroll bar.

MoTeC i2 Training Seminar
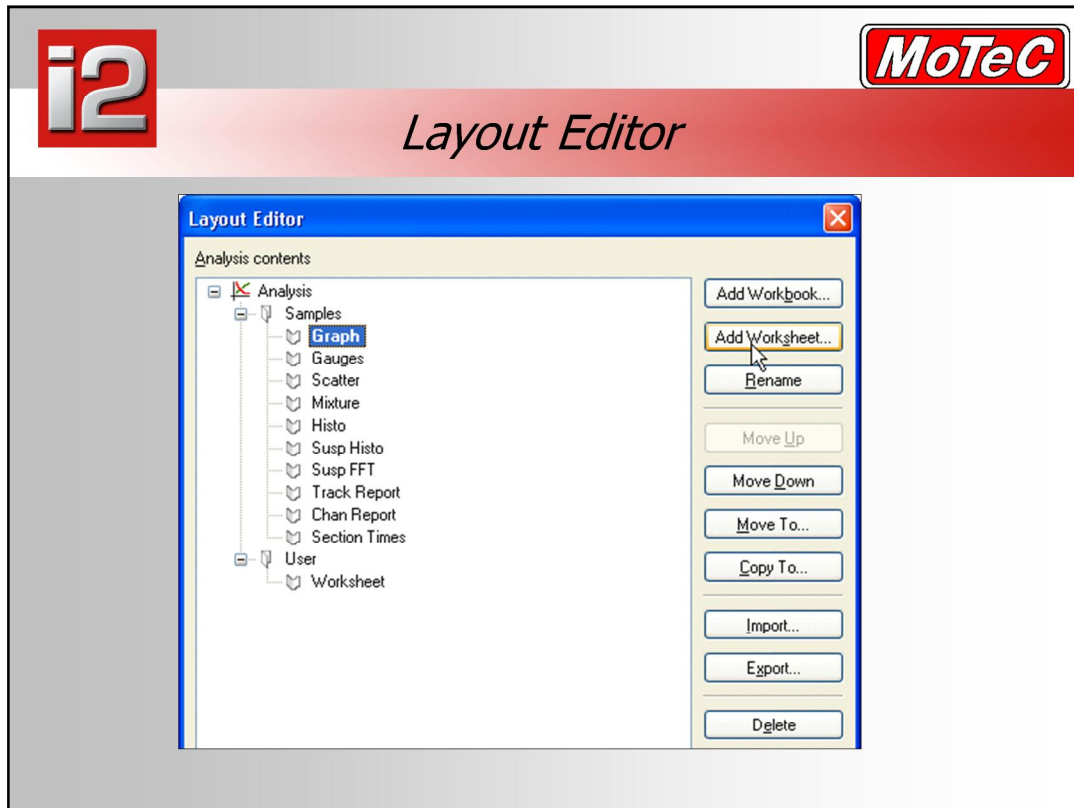
Managing Worksheets and Workbooks

- To create, rename or delete a worksheet right click on the worksheet tab area and select the appropriate item from the menu. Similarly - to create, rename or delete a workbook right click on the workbook selection control. Alternatively press Ctrl+F7 to activate the "Layout Editor ". The Layout Editor can also be used to rearrange the order of worksheets and workbooks as well as rename, delete etc.

- To re-arrange the order of worksheets, highlight one and click on 'Move Up' and 'Move Down' to change it's position.

- Workbooks and Worksheets can be 'Exported', that is, saved as individual files, so they can be imported into other projects or copied to another PC.

- The 'Copy To' function is used to make a copy of a Worksheet in another Workbook.

The most important Keyboard shortcuts

Views

- F8   Data Window
- C   Channel Window
- V   Values Window Off/On
- Esc   Defocus the active window and return focus to the worksheet

Data

- F4   Overlays Off/On
- N   Next Range (eg Lap)
- P   Previous Range (eg Lap)
- F9   Time / Distance mode toggle

Components

- F5   Component Properties
- Tab   Focus next component

Graph

- Left / Right Arrows   Cursor Movement
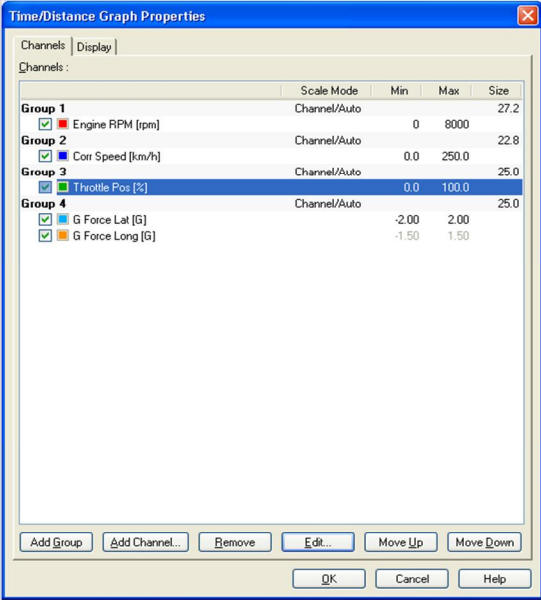- Ctrl + Left / Right Arrows   Fast Cursor Movement:
- Up / Down Arrows   Horizontal Zoom In / Out
- F2   Horizontal Zoom Full Out
- W   Horizontal Zoom to Default (e.g. 1 Lap)
- Shift + Left / Right Arrows   Pan Left / Right
- F3   Variance Off/On
- E   Status & Errors Off/On

- Use the Graph Properties page to add groups – which can contain one ore more channels, and then add channels to those groups. The 'move up' and 'move down' functions apply to groups and channels.

- The Remove function will remove either a single channel or a group, depending on which is selected.

- Channel properties such as scaling and colour can be accessed from this screen by double clicking on a channel, or by selecting a channel then hitting 'Edit'. Note that these are global properties and will be applied wherever this channel appears.

Display - Linking

- By default the cursor is linked across all worksheets and books. This means that a cursor position set on one worksheet will be the in the same position on another worksheet. To change this, go to the particular display element properties (F5) and under "Mode - Link Options" uncheck the box "Cursor linked". The cursor will now be 'local'. Similarly for the Datum cursor – it can be Datum linked to be in the same position on multiple graphs. More on the datum cursor later.

- By default all components are also 'Zoom Linked', when the zoom level changes on a graph, linked components will display data based on the selected zoom level. It is possible to uncheck this option so that a graph can be zoomed independently from other display components.
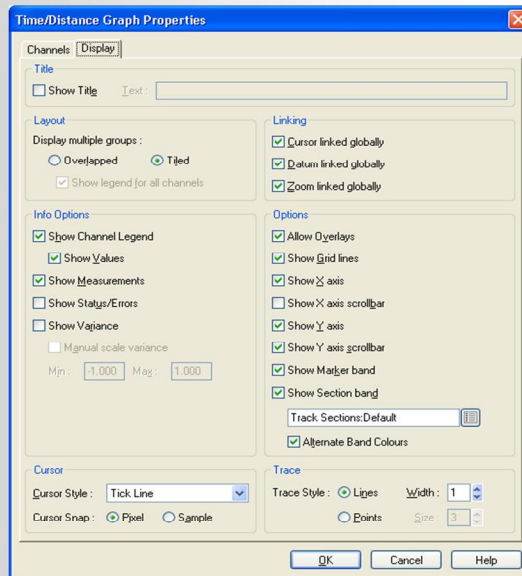
Display

- Sets various options for the appearance of the graph

- By default the X axis scrollbar is turned off. Check the box to turn this back on. This adds a scrollbar at the top of the graph window that can be used to move the graph through the data at the current zoom level. Measurements, Variance and Status/Errors can be toggled with the 'M', 'F3' and 'E' keys respectively. The graph properties can be used for default settings.

Overlapped

- Shortcut key 'G' toggles between Overlapped and Tiled mode. When overlapped all groups are displayed together as though on one graph. Each group still has separate Y axis scaling that can be set by making a channel in that group active then using the scroll bar.

Cursor & Trace

- Select the cursor type, this is selectable for each graph. The traces can be lines or individual data points, line width can also be specified. Showing individual samples allows you to quickly determine if a channel such as damper position is being oversampled.
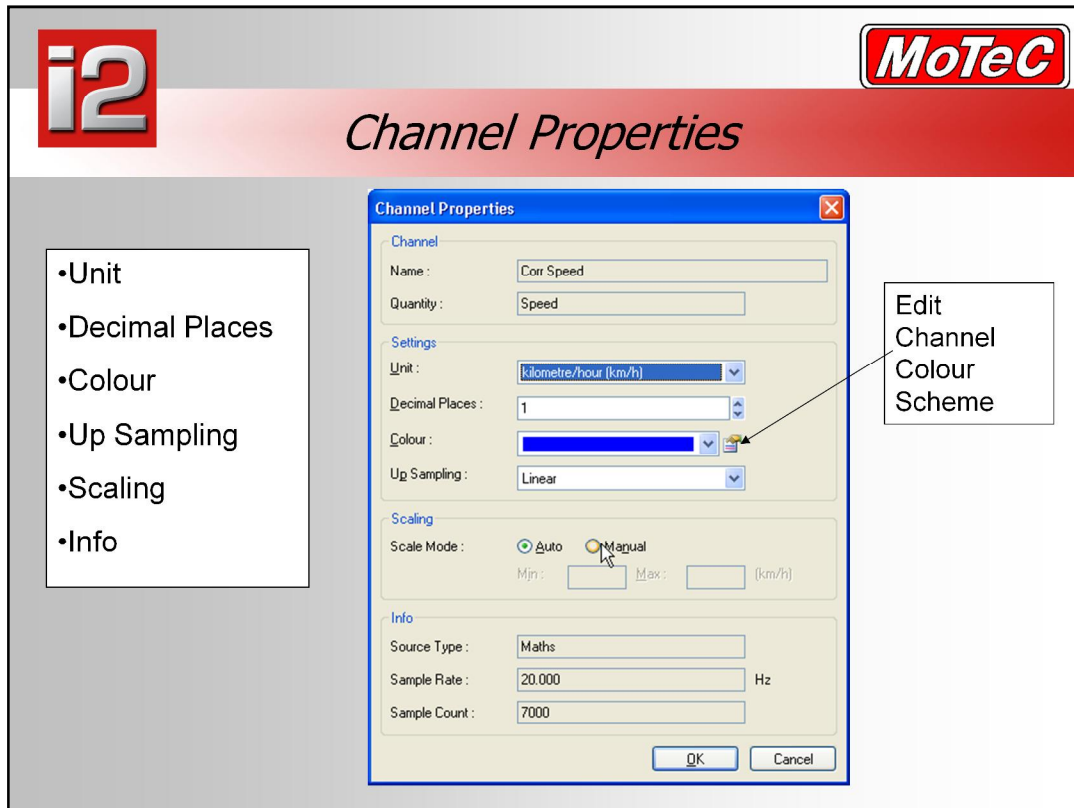
- Channel Name and Quantity (unit type) are shown at the top, these cannot be edited.

- Unit – Display units on all components

- Decimal Places – Displayed on all components

- Colour – The channel will be the same colour in all graphs and gauges. 8 colours are available in a colour scheme, these can be changed by clicking on the icon next to the channel colour selection.There are also complete colour schemes that can be loaded, eg: black backgrounds. See 'Tools – Options – Colours' and then 'Select Scheme'. You can also add colours to your channel colour selection in the same place.

- Up Sampling – how lines are drawn on a graph between sample points. By default this is linear, meaning that a straight line is drawn to join data points. This is generally what you would use, except for on/off channels such as Brake Status.

- Scaling – Manual: A min and max value may be set for each channel. This allows the components to use common scaling avoiding the need to set the min and max for every component. Auto: the various components will auto scale the min and max scale unless they are specifically set to manual scale. Auto scaling can be bad for noisy data as it often expands the trace out beyond the area that you would like to see anyhow.

- Info – general information about the channel: Source Type, the sample (log) rate and number of samples in the file.

- A complete list of channels can be found under 'Tools – Channel Editor', the properties for any channel can then be edited from this screen.

- Right click on a channel name to see the above menu. At the top is shown the channel name along with the logging rate.

- Hide channel - removes the trace from the graph, but leaves the label and channel value.

- Remove channel - removes the channel from the graph. If there are no other channels in the group, the group will be removed and others automatically expanded to fill the available space.

- Edit Maths - is greyed out unless there is a filter or Scale/Offset applied to the channel

- Filter – a channel can be filtered by time or number of samples. This filter is temporary while i2 is open and will be lost the next time i2 is loaded.

- Scale and Offset – Correct or adjust data. Changes are stored as local file maths.

- Zero at Cursor – Correct sensors that have not been zeroed. Changes are stored as local file maths.

- Previous Channel – make previous channel on graph the active channel*

- Next Channel – make the next channel on the graph the active channel*

- Channel Properties – display the channel properties window

  – Active Channel: Each graph has an active channel. A square next to the channel name indicates which is the active channel. This is required for operations that are initiated via keyboard hot keys. For example the hot keys from the active channel menu will operate on the active channel. (eg Ctrl+Shift+F to filter the channel).
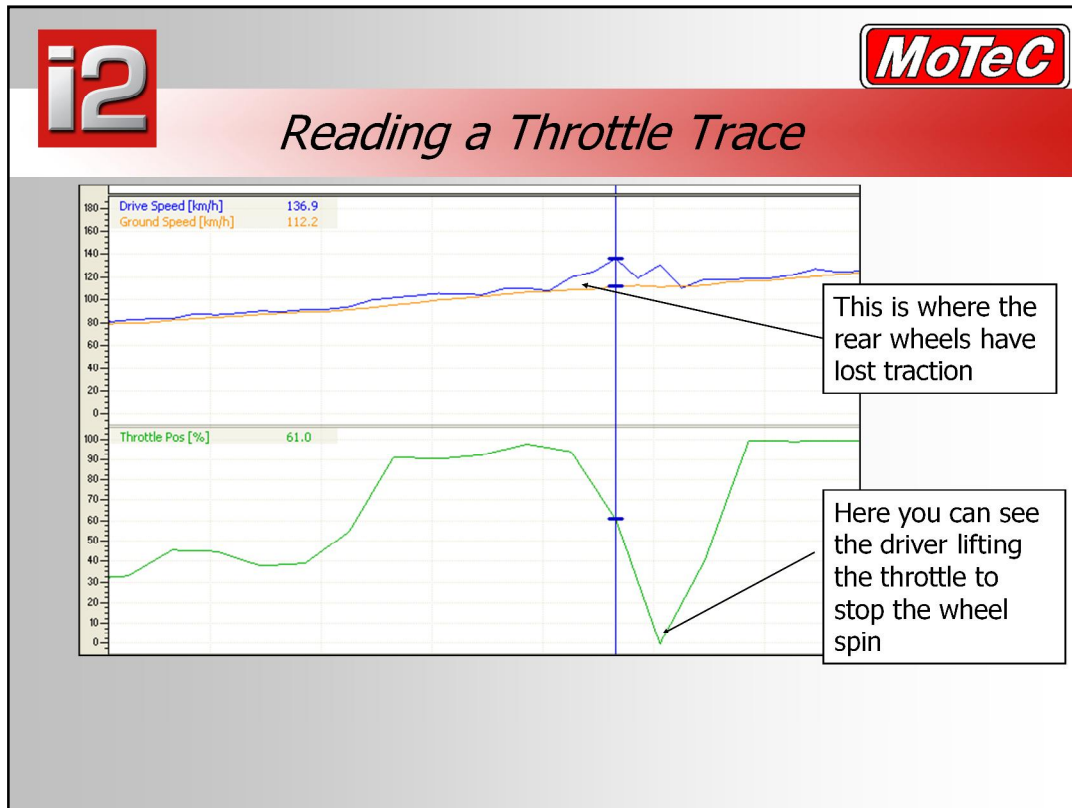
- A throttle trace is one of the most basic, and most widely used sensors in logging. To read the trace we can see that the throttle at the far left starts at 32% throttle opening, and over the period of the graph, goes up to 95% throttle. The graph above is also showing wheel speeds, the ground speed and driven wheel speeds. You can notice where the arrow is, that the drive speed trace moves above the ground speed trace. This is showing the point where the rear wheels have started to spin, as they are going faster than the undriven wheels.

- At the cursor is where the driver has noticed the wheel spin, and has taken his foot off the throttle to stop the wheel spin. Following the drive speed trace along, you can see the wheel spin reduce, the join the ground speed trace again, and it is here that the driver applies the throttle to full again.

- This traces lets you know a few things. The car has enough power to spin the wheels at over 100km/h. You can measure how long it took from the point that the wheels started to spin until the driver took action by reducing throttle. This can be use to compare drivers, looking at their reaction times. You can also start to verify things about the vehicle handling with this data. You may be thinking that the car is oversteering due to springs and shocks, but a trace like this may prove it instead to be a driver issue instead.

- If you are intending to look at reaction time, you need to consider the log rate, the above screen shot was at only 5hz on the throttle position and 10 Hz on the wheel speed. It is recommended for testing like that, you should log your sensors much faster, closer to 20, 50 or even 100 Hz.

1. *Press F9 to select time mode for the graph*
2. *Ensure that you have 'Out Lap 1:34.136' from the file "Calder, i2 data day" from 9:53am selected*
3. *Click your cursor at the 20 second mark*
4. *Press the up arrow to zoom in around the cursor at 20 seconds.*
5. *Here once zoomed in you should see the point where the drive speed gets to 70.1 whilst the undriven or ground speed is only at 5.6 km/h*
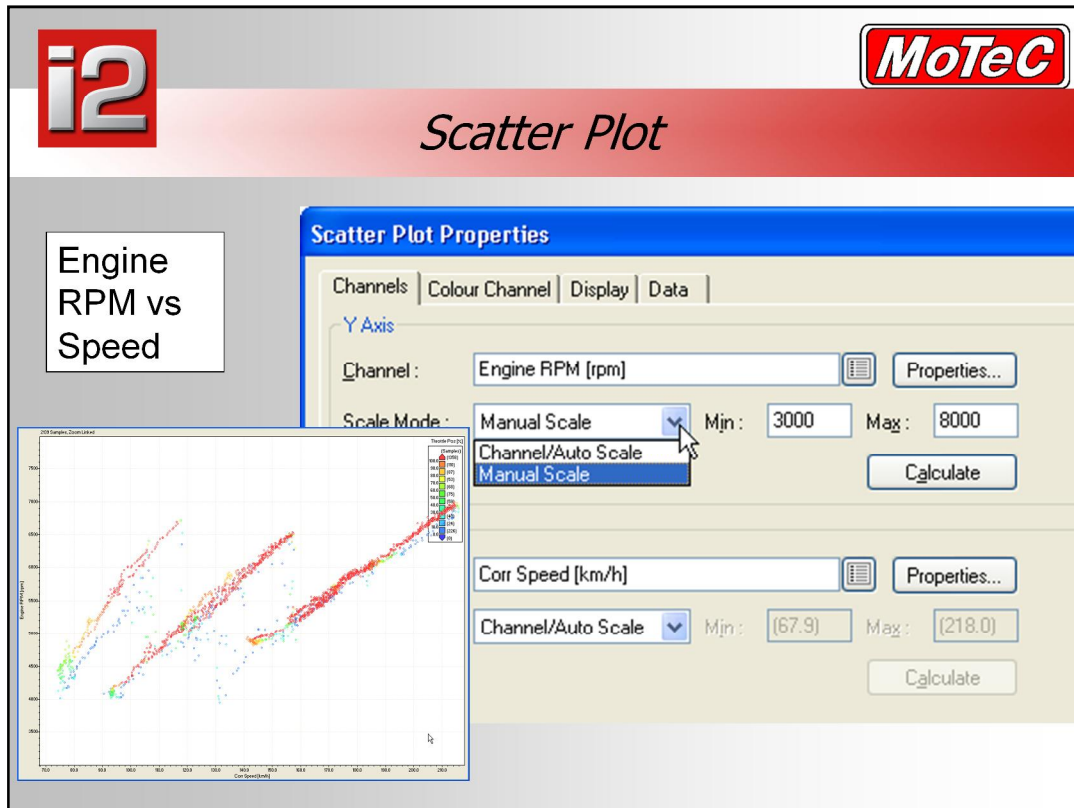
- The scatter plot shows points for two channels where one channel is on the x axis and the other on the y axis allowing for relationships and dependencies between them to be identified.

- By default the Scatter Plot will scale according to the minimum and maximum channel values of the X and Y axis channels. This can be changed by selecting 'Manual Scale' for either channel and entering min and max values. It is zoom linked to other worksheets and will display data based on the current zoom level. To see an entire session worth of data press F2. Select a different lap using the Data window or the lap select bar above the worksheets.

Colour Channel

- The scatter plot allows a 3rd channel to be used to colour each of the data points, the above example uses throttle position as the colour channel. The channel selected is divided in the number of bands specified and colours assigned accordingly. Data can be removed from the plot by unchecking the box next to the range values. This can be used to filter data, eg: by only showing points on the GG diagram when speed is > 50 km/h.

- It is also useful to know that the number of samples logged in the particular band areas is shown on the right of the colour.

1. *Press the up and down arrow to increase and decrease the selected data used to create the scatter plot.*

Brake Bias vs Front Brake Pressure Scatter Plot
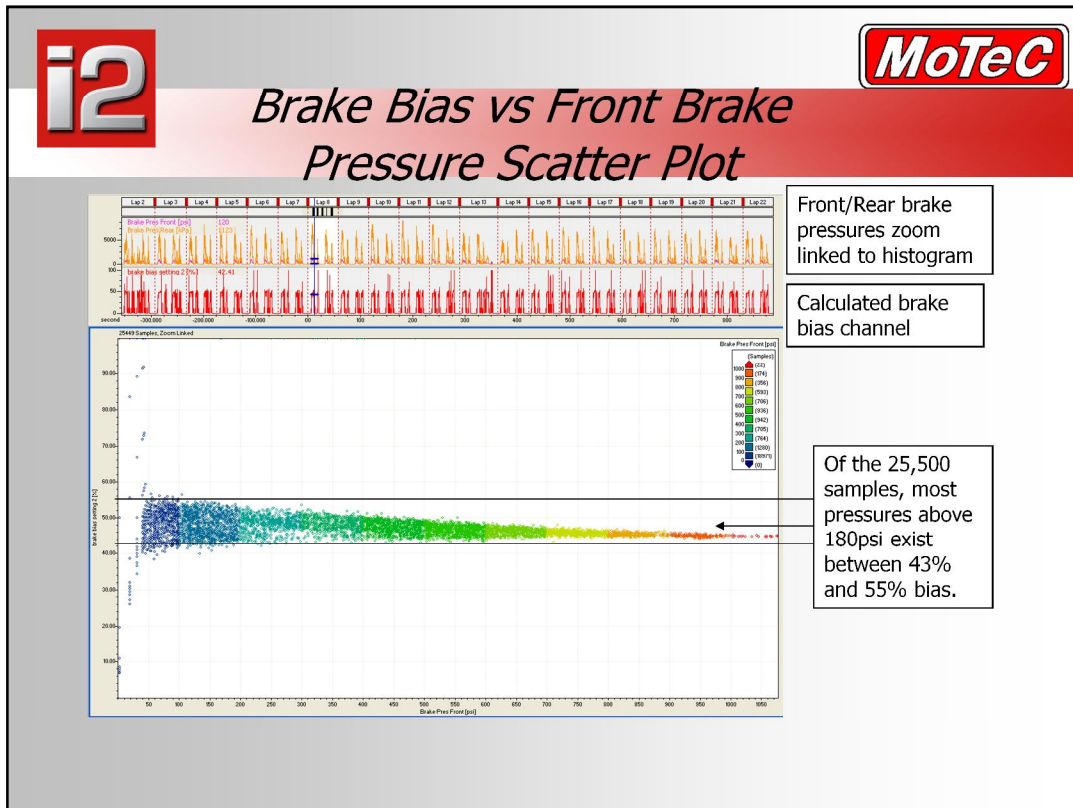
- An XY graph, or Scatter Plot is a graph that shows the relationship between 2 channels. They can be used to represent many things, such as gearing, G-G diagrams, Brake bias, oil temp vs Pressure and much more. In this instance, we are looking at a Brake Bias Scatter Plot. The graph shows brake bias on the Y axis and Front brake pressure on the X axis. What you are being shown above is one dot on the graph per sample of combined brake pressure and brake bias across the selected session. In the example above, there are 25,449 samples across the 24 laps around Calder park raceway.

- In a good brake setup, each time that you press the brake pedal to a given pressure, you should get a consistent amount of pressure going to the front brake lines, and a consistent pressure going to the rear brake lines. The last thing that a driver wants is to press the brakes one time and get mostly front brakes, then do the same thing again and get mostly rear brakes.The integrity of the brake system is the critical element you must minimize. In practice, there is nothing worse than an inconsistent brake system. You can always change your brake pads, rotor or caliper, but if your system does not react the same way each time you use it, you cannot rely on it.

- What the brake bias knob on the dashboard tells you is one thing, and what really happens inside the system may be different, sometimes very different, all because of compliance in the pedal box and master cylinder. That's why it is so interesting to look at changes in the hydraulic brake bias.

- This graph is colored to indicate the front brake pressure. We can see that for small pressures (i.e. for light braking) the brake bias is very inconsistent, but fortunately, it is better when the pressure increases. By plotting this kind of graph, you can either see how consistent your braking system is, or compare two different systems.

1. **Select Workbook "USER"**
2. **Right click on the label "Worksheet" and choose rename, changing the sheet title to "Brake Bias"**
3. **Right click on the empty sheet, choose "ADD", then "Scatter Plot"**
4. **Ensure that you still have out lap (1:34.136) from the Calder, i2 data day file from 9:53am selected**
5. **Click Add type in brake and choose "Brake Pressure Front"**
6. **Select the button next to the channel box listed under X axis, and choose "Brake Bias Setting"**
7. **Select scale mode, and change it to manual, setting the min value to 0, and the max value to 100**
8. **Select the "colour channel" tab, tick the "enable colour channel" box, then select brake pressure front as the colour channel. Click ok.**

Mixture Maps 1

Colour channel legend. Ranges can be turned off/on by clicking on colour box.
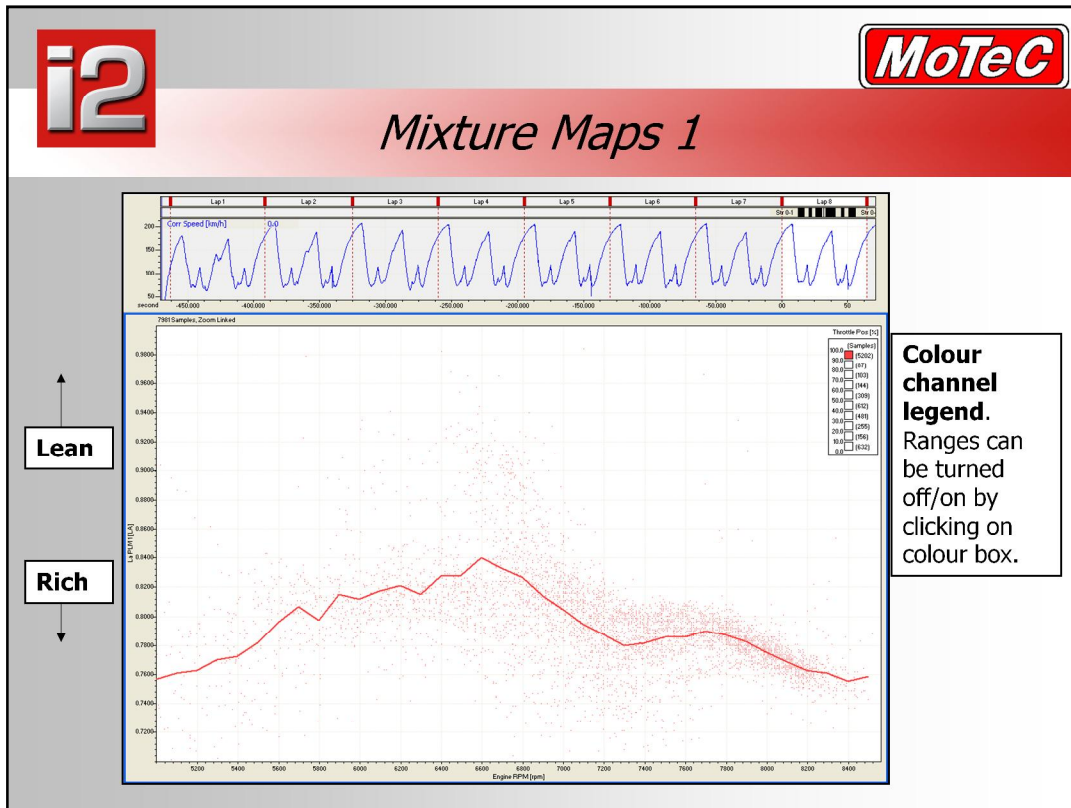
- If you have lambda sensors in your car and data logging on your MoTeC device, you can tune your car at the track, keeping your car well tuned to get the most out of it during racing. This type of tuning is the one of the most accurate methods with the car tuned as it will be raced, including all of the speed induced variables such as inlet air pressure, engine bay temperatures, gearbox and diff temps, barometric pressure variations, and more. It is always worthwhile to fine tune your engine at the track after a dyno session, especially if you are wanting to get it exactly right for when you go racing at a particular track.

- To do this tuning, you need to view engine RPM, load and lambda from when the car is being driven. A way to view the lambda readings for a given RPM range from your logging is to use the **Mixture Map**. This is a specifically designed scatter plot to help show where all the sample points from your lambda sensor readings fall on an RPM vs La scatter plot. This scatter plot has some special features to make it better designed for mixtures.

  - Lambda delay, to allow for sensor reaction time, and more importantly, distance that the lambda sensor is from the engine.

  - Exclusion lambda for untrusted readings

  - Gear filtering, so that any fluctuations to the lambda reading from things such as accel enrichment and the RPM limit don't overly skew the plot.

- The advantage of this method is that it doesn't just look at one example of when the engine was at an RPM and throttle or MAP point, but plots a point every time that engine was there from the selected area of data. It is a very good method of determining the average reading for an engine in that part of the range.

- The down side of this method is that it doesn't show you other considerations that you may see in a full trace, such as engine temperature, manifold pressure, and other sensor readings that can effect the lambda reading lap to lap via compensations that may be being applied by the ECU.

- As with all scatter plots, the average line is created from the collection of samples. The number of samples is shown beside the colour in the legend on the mixture map. If you are using mixture maps, ensure that you don't place too much weight on an average trace made up of only a few samples, increase the zoom area to include more samples in your mixture map.

Multiple Lambda Channels

- If multiple lambda channels are added to a mixture map, then the 'G' key can be used to toggle between different display modes. ie: on separate graphs, then on the one graph and finally showing a single trace that is the average of the selected lambda channels.
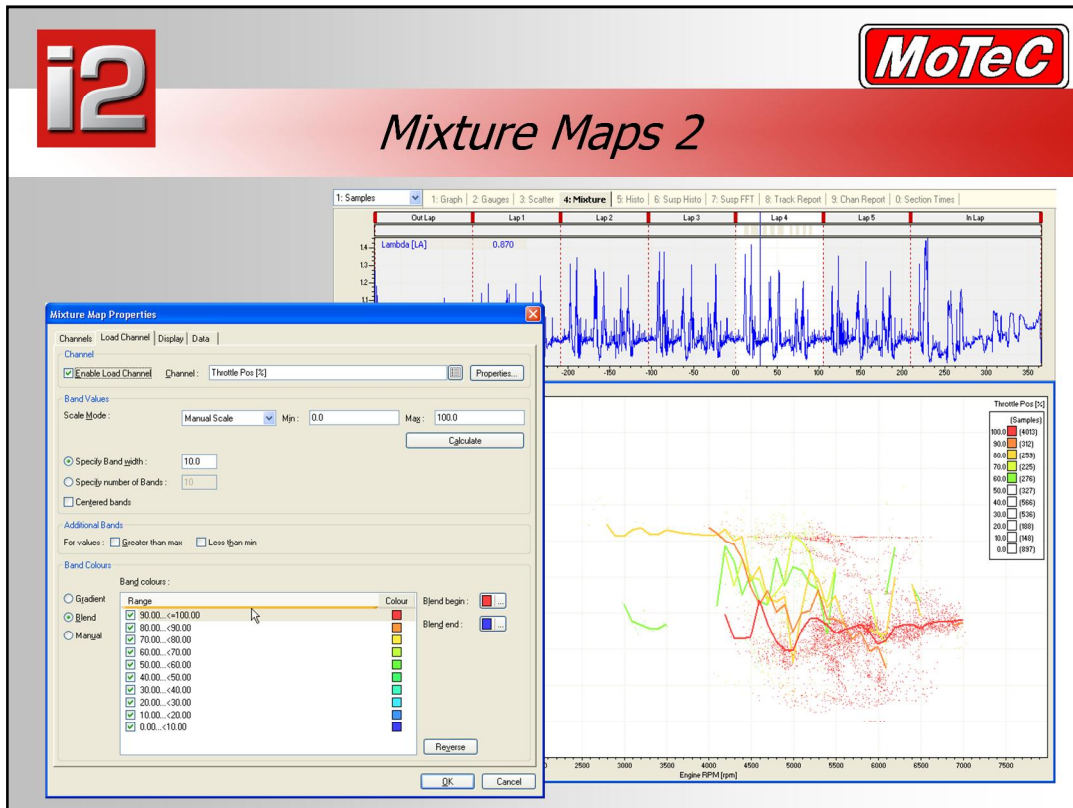
- The Engine RPM Channel and Load Channel must be selected in the component properties dialog to setup the mixture map, they can have different names, Lambda, Lambda 1, Lambda left, PLM lambda 1 etc. The Lambda channel can also be added from the channel window as described in the channels help. This allows the Lambda channel to be readily changed.

- **Load Bands -** The Engine Load channel (normally Throttle Position or Manifold Pressure) can be divided up into a number of bands so that the mixture can be displayed for different engine loads. The spacing between loads can be adjusted to correspond to the load spacing on the engine management system to make ECU adjustment easier.

- **Band Trend Lines -** For each load band a trend line can be displayed. Each load band and associated trend line can be turned off and on in the properties dialog or by using hot keys: Alt+`, Alt +1, Alt2 etc.

- The **Gear Change Filter** is used to exclude data during gear changes a Gear Change Filter is included. The gear filter requires that the rate of change or RPM be specified.

- All Lambda sensors exhibit a delay from actual change in engine mixture to the sensor registering that change. This is due to the time it takes for the exhaust gas to read the sensor element and inherent delays in the sensor. This delay can be allowed for by entering a value in the **Lambda Sensor Delay** parameter.

- **Load Channel Band Values** - Band Width or Number of Bands – dividing the load channel eg: 10 bands of 10% width each for Throttle Position

- Centered Bands – a different way of dividing the Load channel

- Additional Bands – gives you the option of viewing any data that falls outside the Ranges specified. More example if the throttle sensor hi/lo positions have not been set correctly and it is reporting numbers greater than 100%.

- Gear Filter Settings can be set to exclude reading taking while the engine RPM was changing rapidly, ie: during a gear change

1. *Select Workbook "Samples" and Worksheet "Mixture"*
2. *Click on the mixture map space to set the focus to that graph, and press F5 to view its properties*
3. *Click on lambda to highlight it and choose remove, then select Add and type in "LAMB"*
4. *Double click on "Lambda 1", then choose Add again, this time selecting "Lambda 2", then select "OK"*
5. *Click on the empty time distance graph, type in "C" then "LAM" then add both lambdas to the graph.*
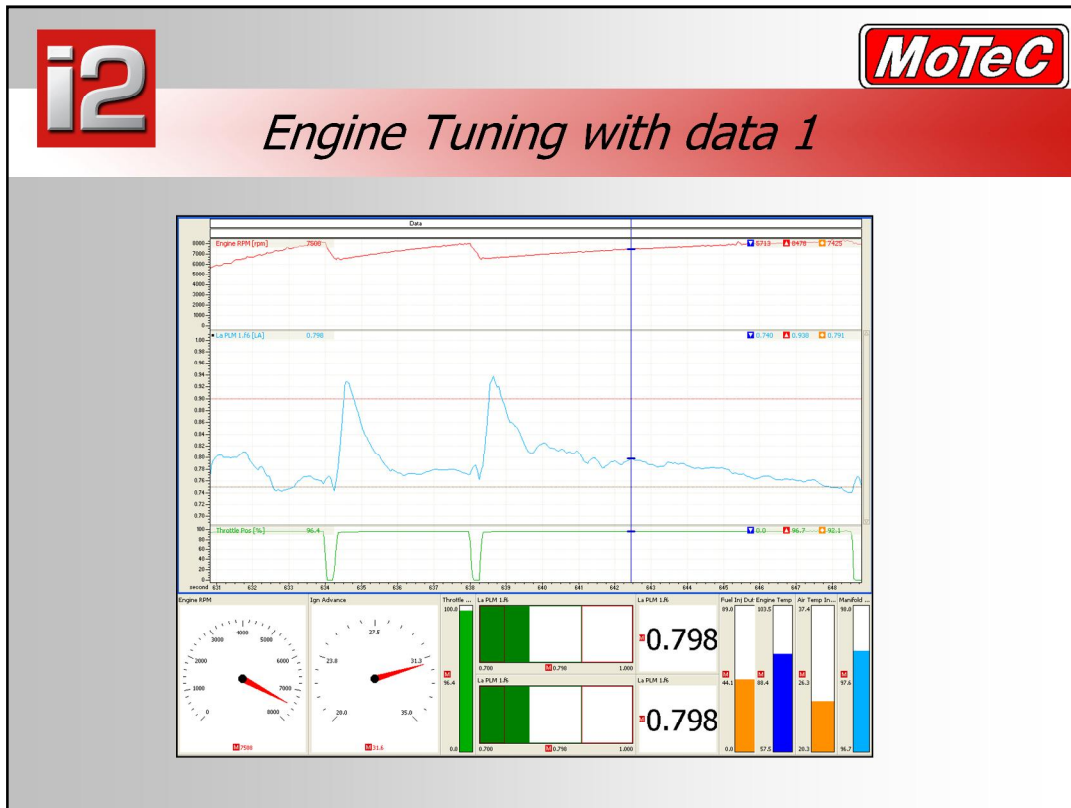
- Another way to look at lambda readings is using a normal time/distance graph display. The advantage of this method is that you can see the data in perspective of where it occurred on the track, and what else was happening at the time.

- Lets look at an example of how to tune a car using the data. In the above example, you can see the engine rpm in both gauge and the red trace. You can also see the lambda reading as a blue trace, bar graph, and numeric gauge - can't have too many representations of this! Other important pieces of information here are the temperatures, manifold pressure and ignition advance. Assuming that this engine is tuned by throttle position, we should look at the readings at the cursor.

  - RPM 7500
  - Lambda 0.798
  - Throttle position 96.4% (the throttle position sensor doesn't appear to have been calibrated correctly here. Reset the Hi/Lo values!)

- OK, noting this information down, we can go off to ECU manager to modify the fuelling of the engine.

- Other things to note on this screen are the min and max lines on the Lambda panel of the Time Distance graph. See the red and brown dotted line on the lambda trace. You can input these lines yourself, I have put them at a Min of 0.75 and Max of 0.9 These are my limits of where I would like to see the tune of my engine. Also on the bar graph at the bottom, you can see that the lambda trace is green. I have set it up so that when the trace goes over lambda 0.9, the bar goes red, and under 0.75, the trace goes brown. This is a good way to emphasise the range that you want your sensors to read in.

1. *Click on Workbook list, and select "User"*
2. *Right click on "Brake bias" worksheet tab, and select new worksheet, calling it "Lambda"*
3. *Right click on worksheet space, and select "Add" then "Time Distance Graph"*
4. *From the next panel, select "Add channel", then add "Engine RPM", "Lambda1", "Lambda2" and "throttle position"*
5. *Press W to show a whole lap, then click at the 34 second mark, and use the up arrow to zoom in on the data.*
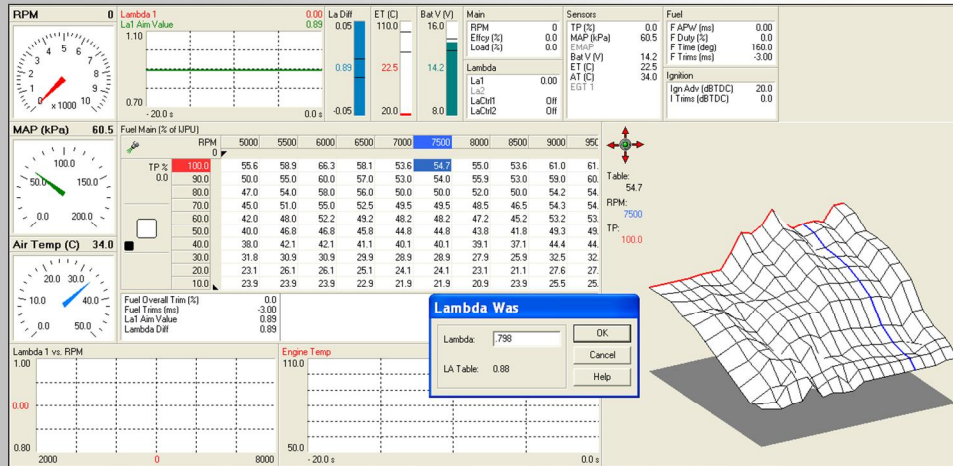
- Once you have your lambda reading, throttle position and RPM of the site that you want to tune, you go into your MoTeC ECU manager software and to your fuel table. In here you move your cursor to the site that you wish to tune, in our case 7500rpm, and 100% throttle. By Pressing L in this cell, , a screen, as shown above, pops up and asks you to enter what the lambda reading actually was at that site when the engine was running. The ECU program then works out what the number that should have been in the fuel table to achieve the lambda reading that you have requested in the lambda table. By doing this for each site in the fuel table, you can perfect your engine tune without having to tune as you drive, or go to the dyno.

- Be aware of other things when looking at the data to tune the engine. The Engine will show variable readings when it hits the Rev limiter or traction control cuts in, dependent on the settings in the ECU. The lambda readings will also be variable during acceleration enrichment and other times when you are moving the throttle such as during gear changes. The readings are still correct, but can vary significantly. With a race car, you would spend most of the time tuning full throttle and off throttle sections at the track, the steady state areas.
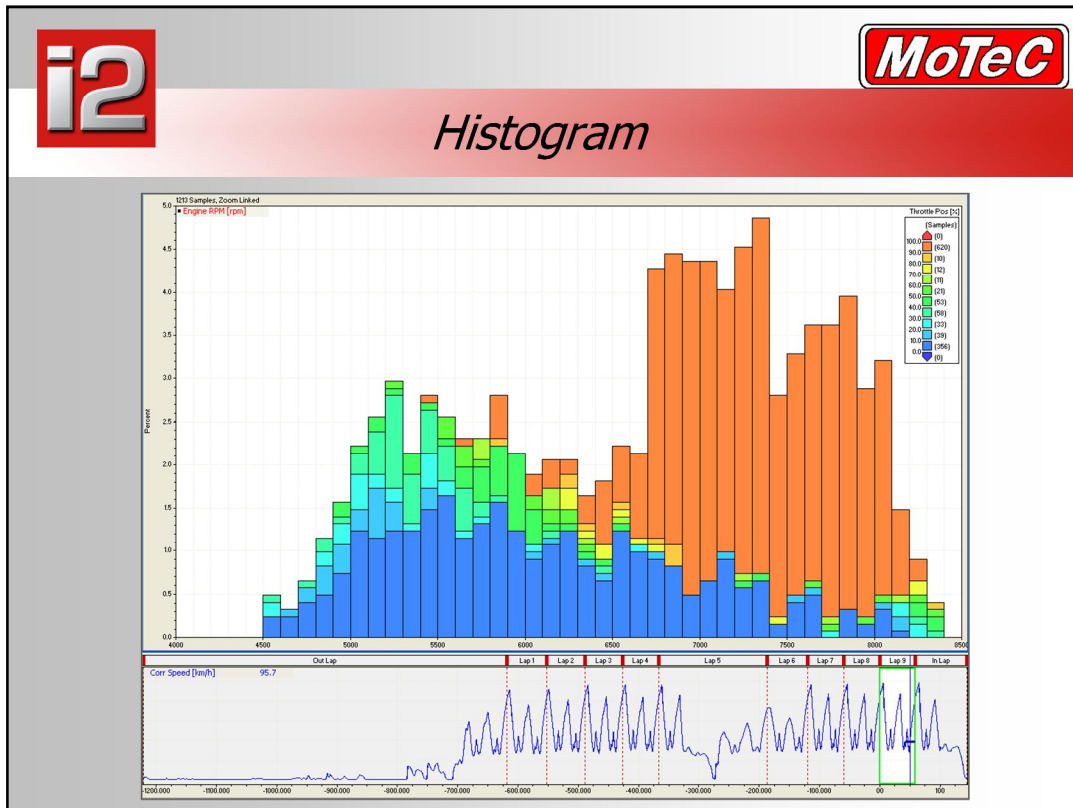
- The Histogram consists of a user definable number of bins that the logged data is placed into which shows how often a certain channel values have occurred.

- The histogram may be displayed in various styles: bar, line and text and may be optionally colour coded against another channel. For example: If RPM is selected, it can be useful in determining where the engine is spending most of its time and therefore identifying where the development effort should be targeted, as well as identifying maximum revs and the duration of time spent there.

- The duration of the Histogram can be for a single lap the entire session or a zoomed section. Use zoom functions on a graph to select the time period you wish to view. ie: The outing graph above is used to control what part of the outing that the histogram is being calculated from. This can be changed using the normal zoom keys, up/down or the mouse thumbwheel.

Colour Channel

- The histogram may be colour coded against another channel. The bar chart 'stacks' are divided according to the value of another channel, eg: throttle position on top of Engine rpm as above. In the Histogram Properties, select the 'Colour' tab, then select the secondary channel. The rest of the page gives options for the colour channel range and the number of colour bands
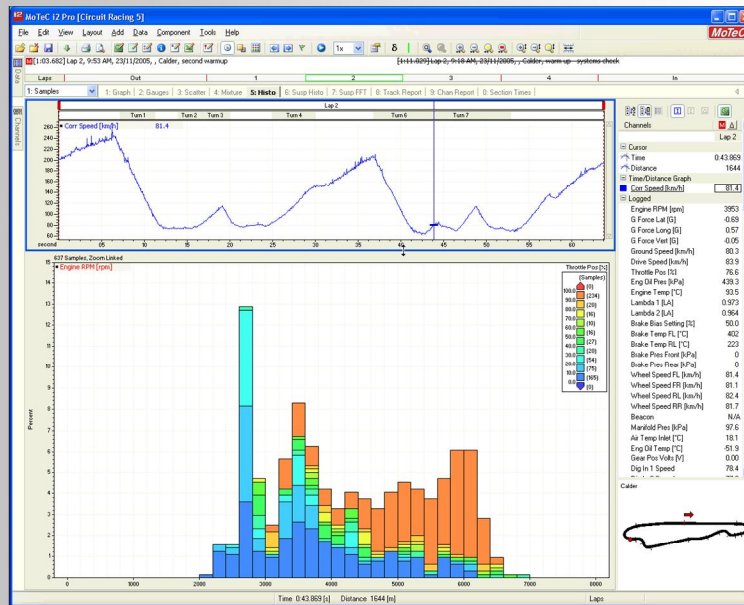
Data Export

- The histogram data may be exported as a csv file by selecting Export Data from the Component menu. The csv file may be used in Excel or other compatible program.

1. **Select Workbook "Samples"**
2. **Press "5" to select the histogram worksheet**
3. **Press W to select the whole current lap of data**.

Zoom Linking

- The data that is displayed is normally for the currently selected range (normally a run or a lap). All graphs, histograms, track reports, FFTs, Scatter Plots and Mixture Maps are "Zoom Linked". This means that changing the zoom level on one graph will change the zoom level on all graphs. This changes the amount of data shown on the other linked display elements. This allows you to zoom in on one corner, for example, and view the suspension data just for that area.

- Display elements are also 'zoom linked' across work book/sheets. This way you can change the zoom level on one sheet and then see the same data section on another sheet.

- For display components such as Scatter Plots and Histograms, the shortcut keys 'F2' and 'W' still apply. To zoom within a lap or across multiple laps use a graph to select the zoom level.

- It is possible to disable zoom linking for a specific component by going into the Properties page and unchecking the box for 'Zoom Linking'.
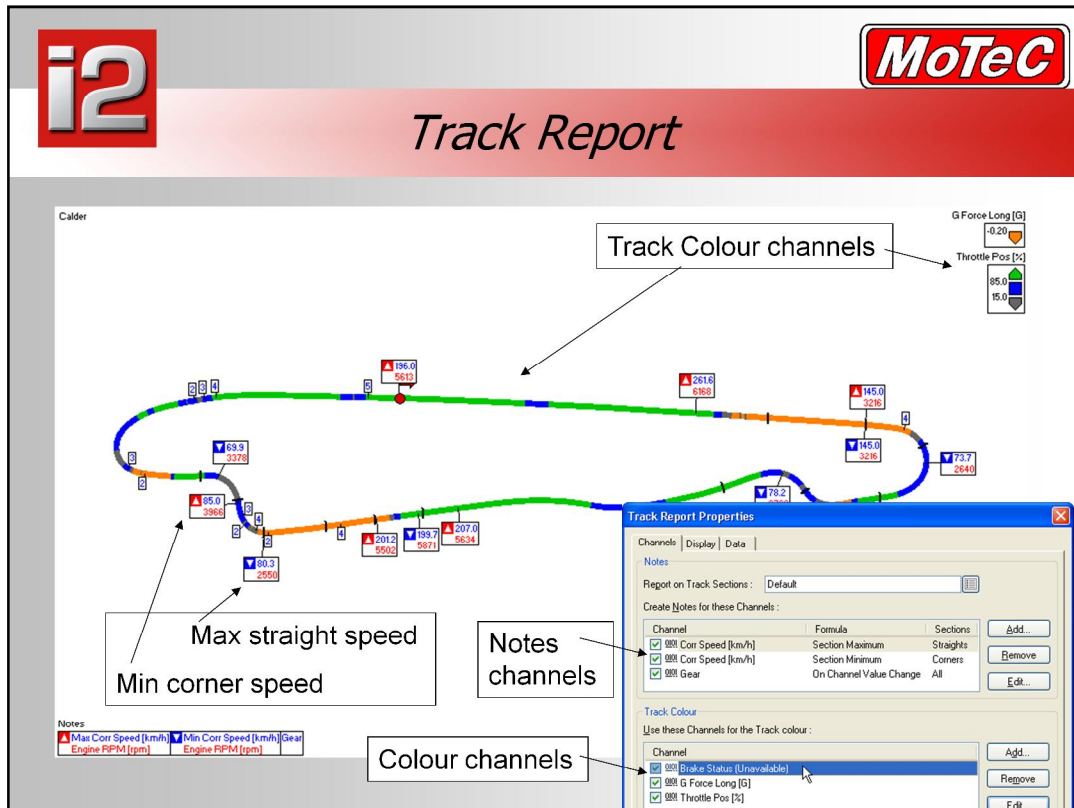
- The Track Report shows channel statistics on a track map based on track sections. The channels shown are fully configurable with a statistical calculation performed over the section in question. Press F5 to see report properties and select the channels shown. They can also be displayed for a particular section type only, eg: Max Speed on the straights, min Speed on the corners. The report may use the default sections or user defined sections. The notes point to the position on the track at which the event occurred. This means that engine rpm is shown at the point of maximum speed, for example.

- The notes may be moved by dragging them if their positioning is not suitable. It is worth remembering that once a note is dragged all others will maintain their positions until "Automatic Note placement" is reselected under Properties - Display.

- Additional channels can be used to 'colour' the track. These are added in layers with a channel lower in the list only being visible if the channels above it are not being displayed at that point.

1. **Press the "8" key to choose the track report worksheet**
2. **Press the V button to toggle the values on and off**
3. **Click on the track to move the position cursor, hold and drag it to make it move**
4. **Press A to make it animate at realtime speeds**
5. **Press F5 to show the properties of the track report**
6. **Click Add under Create Notes, Select the button next to channel, and choose "G force Long"**
7. **Choose the formula for section maximum, then "ok" and "ok" to display it.**
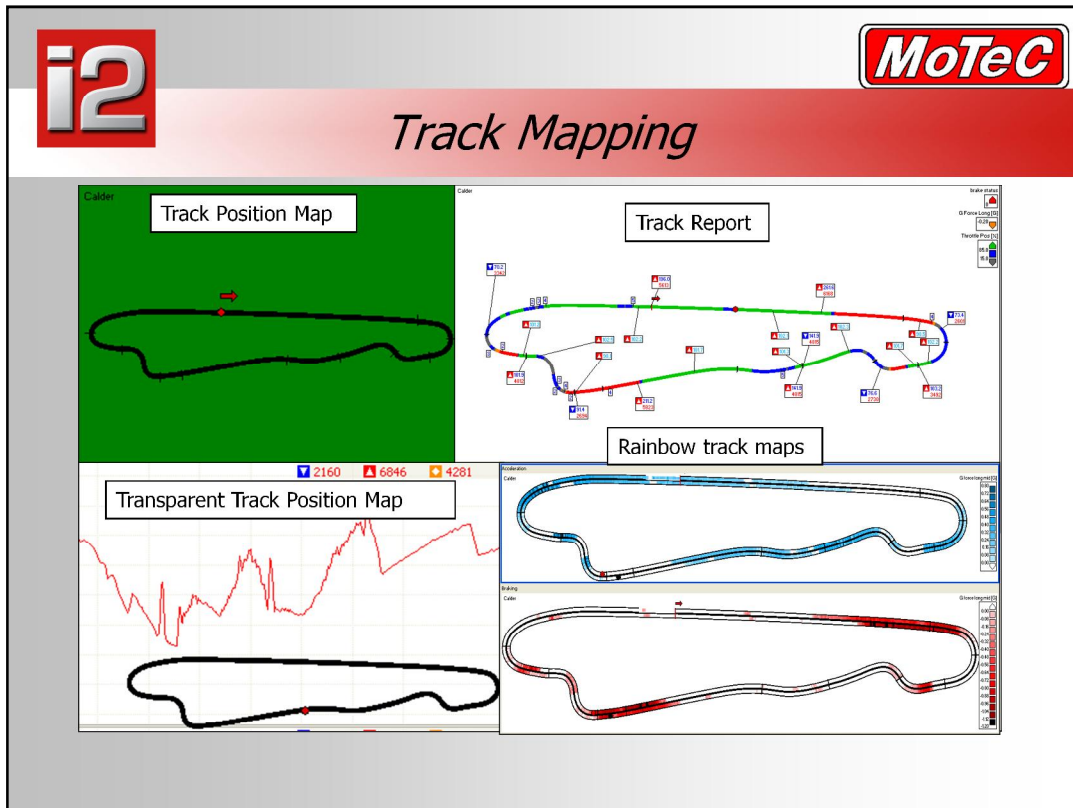
- A track map provides a graphical representation of the venue at which the logged data was acquired. For this function to be available it is necessary for the following inputs to be logged: lateral G force, vehicle speed and a lap beacon. Or GPS data and a beacon. The software will then derive a map based upon the driving line of the fastest lap in the log file. The map allows the user to relate the data to the specific track position where an event has occurred.

- In i2 Track maps can be used to show a graphical representation of data logged in the log file. It can of course show the channels Throttle position, Brake active and Gear, but can also be used to show oil pressure across a lap, or braking pressures for instance, as shown in the rainbow track map examples above.

1. **Select the workbook "User", the add a new worksheet by right clicking on the worksheet name area**
2. **Call this sheet "Rainbow Track Map", then right click on the page, then select "Add", "rainbow track map"**
3. **Click on the button to the right of the "Colour Channel " box, and choose "G force long"**
4. **Click on the number of bands, and change it to 5, click the "reverse" button, then finish with "OK"**
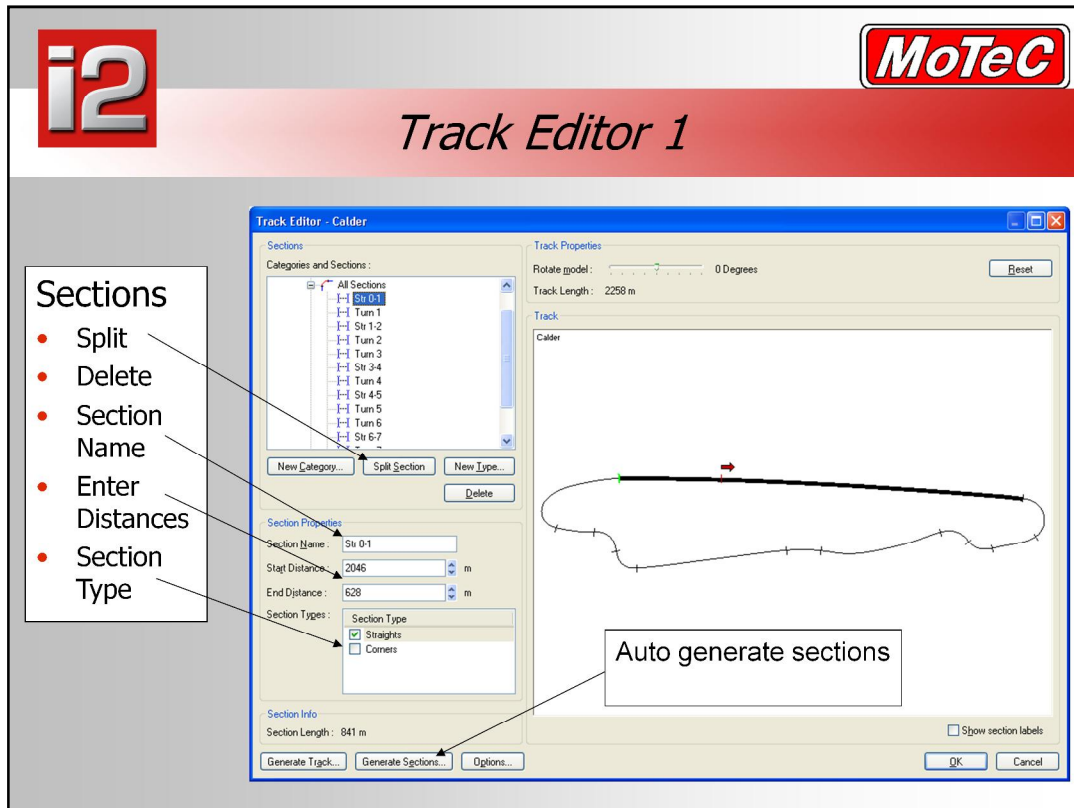
Track Editor 1

- The Track Editor is used to generate/regenerate a track map, create/modify sections and add new section categories. These can then be used to generate a time report or channel report. Eg: divide the track into 3 sectors for a time report.

- The Track Editor can be accessed from the menu 'Tools – Track Editor', by right-clicking on a track report and selecting 'track editor' or by right-clicking on any track map and selecting 'track editor'.

- A track map will automatically be generated from data from the fastest lap that is selected on a venue for which no track map currently exists. Track map generation requires that certain channels are included in the log data: Beacon, Wheel Speed, Lateral G. Also useful is Longitudinal G, which can be used for generating Corr Speed.

1. **Select workbook "Samples", and press "8", "Track Report"**

- Generate Track
  - Distance Channel
  - Lateral G Channel
  - Track Length
  - Track Type
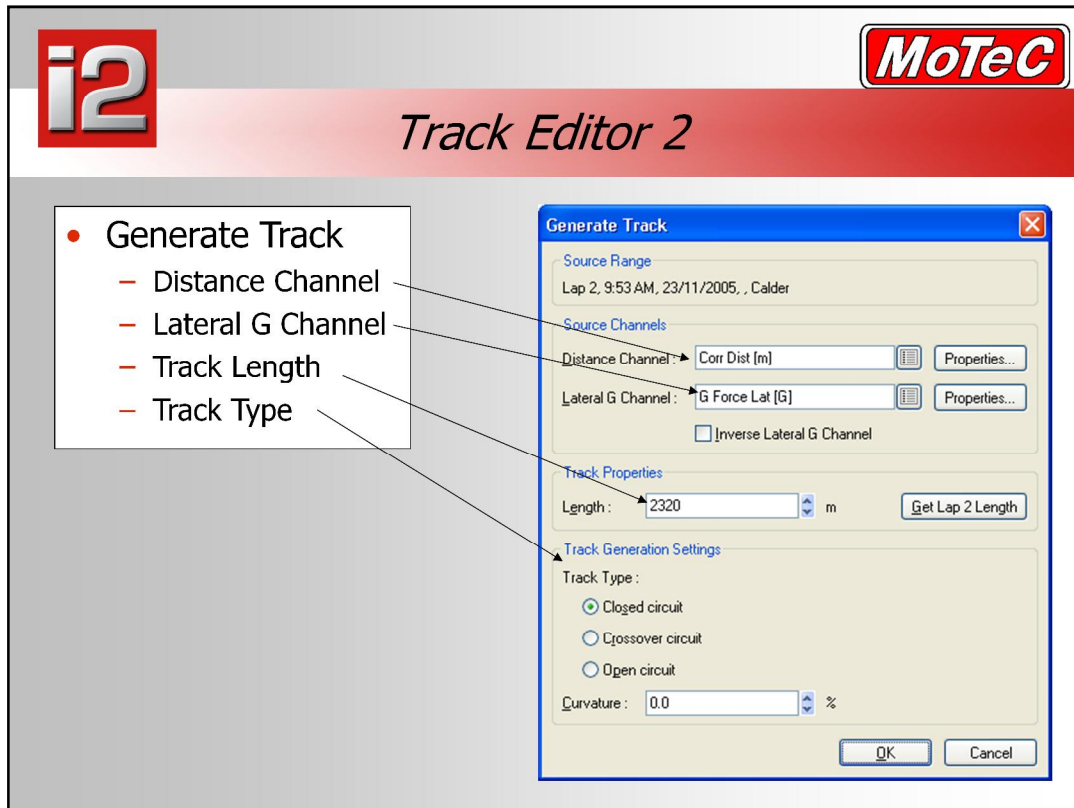
- Distance Channel is 'Corr Dist' by default and lateral G is 'G Force Lat', other channels can be selected using the button next to the channel name. There is an option to use an invert of the lateral G channel if the sensor calibration had been reversed. The track length can be entered manually or use the calculated length of the current lap. If the length is changed, the shape will remain the same, but the map is rescaled to the new distance.

- The 'Curvature' parameter will alter how "sharp" the corners are, a positive number will make the turns tighter, a negative number will do the opposite. This number can be set between –100 and +100.

- Note that after regenerating a track map, the sections may need to be recalculated. This is done from the main Track Editor page. Again the distance and lateral G channels can be selected, along with a 'lateral G threshold'. This determines the changeover value between straights and corners.
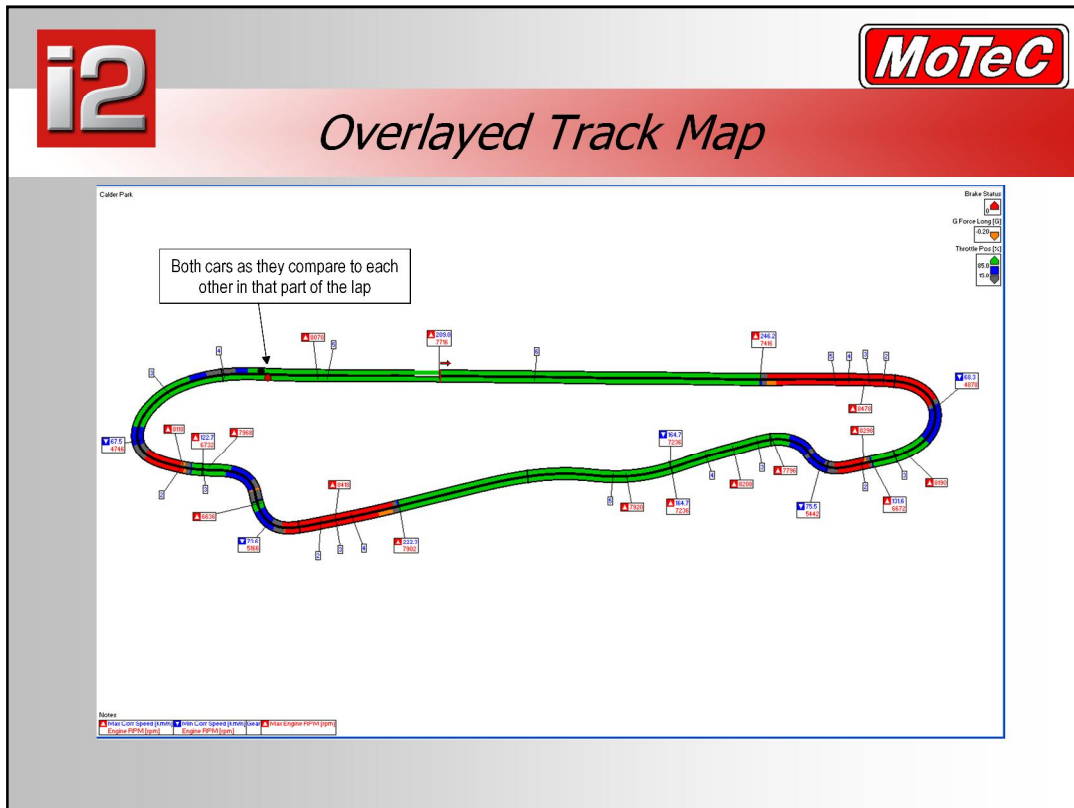
- The overlay track mapping is a new feature in i2, and is an excellent way to visualise just where one car is gaining on another, or determining where one lap is better than another. By pressing the "A" key, you can animate the two dots and "redrive" the laps in realtime, a great way to help explain what is happening in the data to those not particularly experienced in data logging.

- You can mix the overlayed track map with gauges and graphs to get a full feel for all of the happenings of the two overlayed laps.

1. **Press F8, and select lap 2 (1:03.682) from the Calder, i2 data day file from 9:53am in the main column**

2. **Select lap 3, (1:05.19) in the reference "R" column**

- The Channel Report shows channel statistics in a tabular form.
- The report may be configured to report on various ranges including:
- Report on Laps for All Laps
- Report on Laps for the Selected Laps
- Report On Sections for Selected laps (either the default sections or user defined sections may be used)
- The statistics available are:
  Average, Minimum, Maximum, Absolute Maximum, Start Value, End Value, Value Change & Standard Deviation.
- Reports for selected laps (not all laps) can also display data from the Reference and Overlay laps when these are selected. Also shown is the difference between the Main and Reference laps.

1. **Press "9" or select "Chan Report" from the "Samples workbook"**
2. **Click on the top channel report to give it focus and press "f5"**
3. **Select "Add" then search for fuel pressure and double click on it.**
4. **Turn on the tick box for minimum, and click "OK"**

- The *i2* Channel report is the best way to get summary data about your outing. This data is often under utilised but can be a very powerful tool for trying to maintain the reliability of your vehicle. By checking this information at the end of each session you may notice trends in the temps, pressures, speeds or voltages of your vehicle.

- This screen can show you the data in a lap by lap arrangement, useful to make sure that the data is from a lap where the car is at racing speeds. This is important to consider as there is no use looking at the minimum oil pressure on a lap when the engine was not running, or taking engine temp from a lap where the vehicle is stationary and heat soak is affecting temperature readings.

- The data can also be shown in an outings mode where it just shows the min/max readings for an outing. You can even choose to exclude 'untrusted laps' which means that it doesn't include data from your in or out laps in the calculations of you statistics, a problem that often skews statistics of an outing.

- It is useful to then store those outing stats using the "export to clipboard" function, to create an ongoing spreadsheet of races and sessions as per the next slide.

- Here is a sample of a race summary sheet. You can see that it lists summary information of selected channels from each session of an event, and the tabs at the bottom shows the other events of the year. The file is created by exporting out information from the Channel Report screen and pasting it into a spreadsheet. This gives you a useful ongoing record of important pieces of information about your vehicle. It can be used to bring attention to trends in your data of changes in oil pressure, battery voltage, diff temps, gearbox temps, whatever is useful to measure for your particular vehicle. With this data, when you ask, "Is it normal for the gearbox to run at that temperature? At this track?", you can quickly go over pervious sessions, races, and years to see what you should expect from your vehicle. Using the i2 channel reports to create these summary sheets can help increase the reliability of your racing.

- Note that it is very helpful to note information such as ambient air temperature and track temperature with your details and then including them with the summary spreadsheet.

Time Report

	Lap 1	Lap 2	Lap 3	Lap 4	Eclectic	Rolling Minimum
Main Str (End)	0:07.275	0:07.151	0:07.462	**0:07.079**	0:07.079	0:07.079
Turn 1	0:04.158	0:04.141	0:04.467	**0:04.139**	0:04.139	0:04.139
Str 2-3	0:02.710	0:02.609	0:02.574	**0:02.638**	0:02.574	0:02.638
Turn 2	0:02.787	0:02.649	0:02.688	**0:02.661**	0:02.649	0:02.661
Turn 3	0:03.616	0:03.500	0:03.573	**0:03.557**	0:03.500	0:03.557
Str 3-4	0:05.155	0:04.900	0:04.965	**0:05.044**	0:04.900	0:05.044
Turn 4	0:05.336	0:05.098	0:05.140	**0:04.899**	0:04.899	0:04.899
Back Straight	0:07.050	0:06.726	0:06.955	**0:06.701**	0:06.701	0:06.701
Turn 5	0:01.829	0:01.681	0:01.897	**0:01.763**	0:01.681	0:01.763
Turn 6	0:02.770	0:02.693	0:02.978	**0:02.725**	0:02.693	0:02.725
Turn 7	0:11.749	0:11.730	0:12.028	**0:11.491**	0:11.491	0:11.491
Main Str (Start)	0:10.723	0:10.800	**0:10.459**	0:11.055	0:10.459	0:10.459
Totals	1:05.163	1:03.682	1:05.192	1:03.759	1:02.770	1:03.162

Section Times

Split Times

Time Report - Track Sections (All Laps)

	Lap 1	Lap 2	Lap 3	Lap 4	Eclectic	Rolling Minimum
Split 1	0:18.894	0:18.301	0:19.027	**0:18.331**	0:18.301	0:18.331
Split 2	0:32.856	0:31.888	0:32.806	**0:31.666**	0:31.666	0:31.666
Split 3	0:13.413	0:13.493	**0:13.359**	0:13.762	0:13.359	0:13.359
Totals	1:05.163	1:03.682	1:05.192	1:03.759	1:03.326	1:03.356

- The Time Report shows split times in a tabular form. The sections that are used may be the default sections or user defined sections.

Eclectic

- The Eclectic column shows the minimum times for each section and totals them to show the best possible time if all sections could be completed in the minimum times. This can be a bit unrealistic as driving line etc can affect the times from one section to the next so the minimum times can't be joined up in practice.

Rolling Minimum

- The rolling minimum shows the set of consecutive section times that form the minimum overall time for a complete lap. These times are highlighted in bold to easily determine where this starts, ie: it will typically be spread across 2 laps.

Sections

- To change the sections used, go to the Time Report properties (F5) then 'Data – Ranges – Report on:' and select the section type – Defaults, User Defined or Splits (if available).

1. **Press the "0" key, or choose section times to select the section times report.**

- Similar to channel statistics, **i2** can create reports based on time around the track, called a "Time Report". These time reports are used to further examine the detail about where you were fast and where you were slow, section by section across the whole lap.

- You can report on:
  – All sections
  – Corner sections only
  – Straights sections only
  – Custom sections only
  – Split beacon sections

- You can create a report such as the one in the top right corner which shows times for the 4 lap outing, only when the car was going around corners as shown by the section markers on the track. The red line indicates the rolling minimum lap time. The rolling minimum is the fastest lap that the car did for that outing regardless of where the Start/Finish line is. It may start and finish on the back straight, instead of the at the start finish line. It is good indication of a lap that the car is capable of doing, as it was actually driven, but can be effected by an artificially fast section, such as forgetting to brake at all for a corner – check adjacent section times to see if it is a realistic time.

- The eclectic lap time is a collection of all the fastest sections from the outing. It is an indication of how fast the car may be able to go, and the included section times are indicated in the blue above. It doesn't necessarily indicate a lap that could really be driven, given that going faster in one sector may preclude a driver from going quickly through the next section, such as braking too late into a corner.

Values Box

- Hide/Show Track Map
- Time and Distance at Cursor
- Channels on graph with focus and active channel
- Values of all Channels
- Show difference between Main and Ref laps

- The Values box shows channel values at the cursor for all channels, with those on the focused graph listed at the top.

- When Reference and Overlay laps are shown their values are shown in additional columns.

- The Values box can be toggled On/Off using the 'V' key.

- It is also possible to show the difference between the Main and Reference laps by clicking on the 'delta' symbol at the top of the column. Whichever column is selected is used as a bas, with the other columns showing the difference. eg: in the above example the Main lap column shows channel values, while the Ref lap column shows the difference to the Ref lap.

Save Project Settings

Saving project settings

Start with same project

Start where you left off
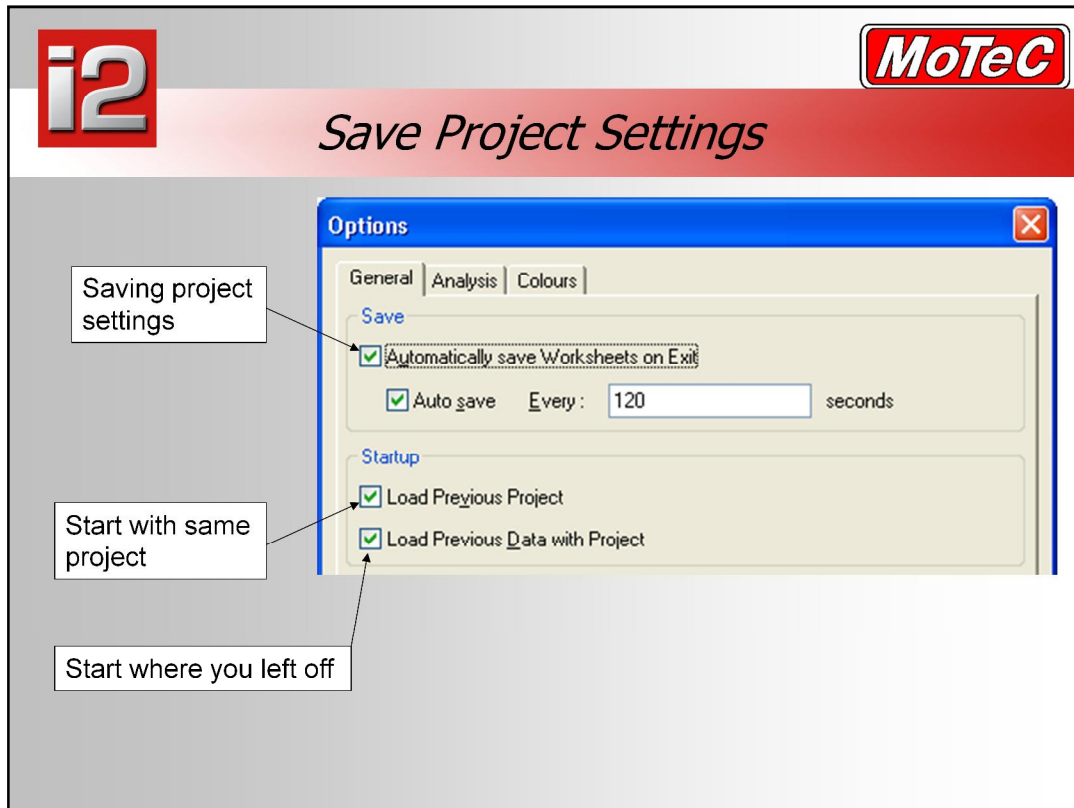
- At any time go to 'File – Save All Settings'.
- Under 'Tools – Options', there is an option to enable 'auto-save' of settings at a specified time interval
- Additionally, all changes are saved automatically when exiting the program

Analysis

- Load data after device unload – data can be downloaded directly from i2 by going to 'File – Get Logged Data'. When this option is checked that data will be loaded into i2 automatically.
- Autoscale options. in general for circuit racing untrusted data is from in/out laps. This data is not used in autoscale as it often contains values outside that seen during a race.

Colours

- Change individual colours or select an overall colour scheme.
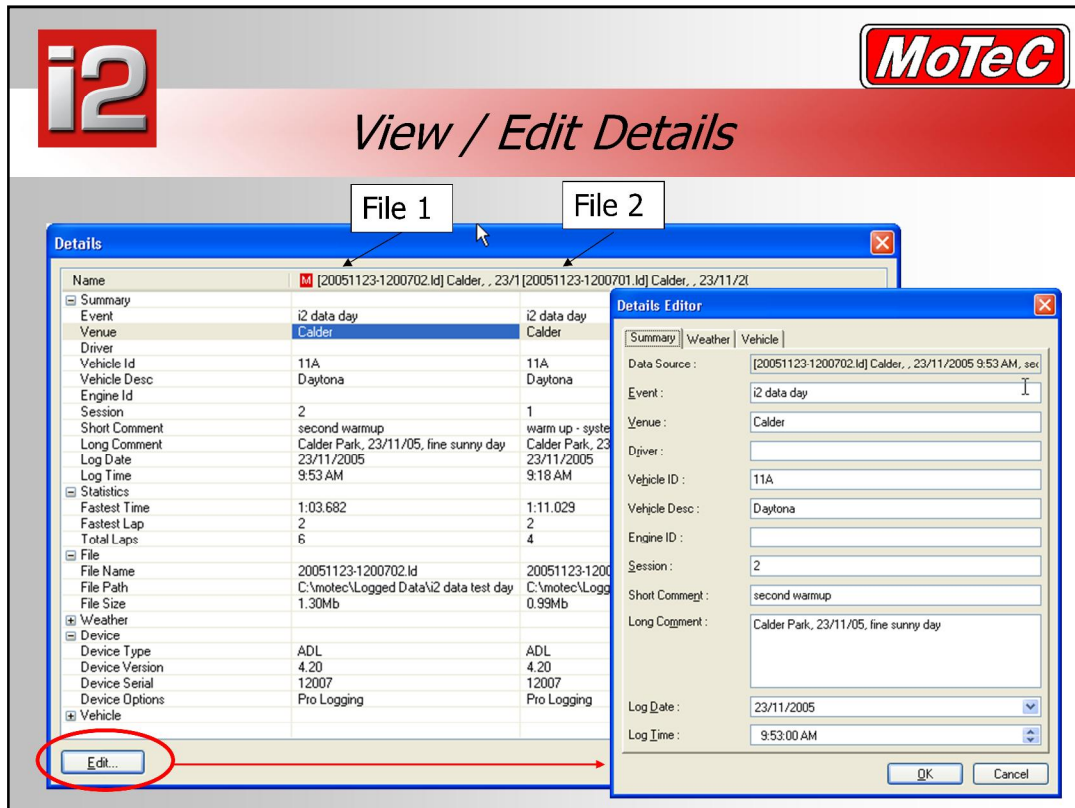
- The menu item 'Tool – Details', or 'Ctrl + D' keyboard shortcut will bring up a window with details for all the files that are currently open. Groups of detailed information can be expanded and collapsed using the +/- symbols on the left of the window.

- Click on the 'Edit' button to bring up a 'Details Editor' window. Most of the details listed can be edited or added if they had been left empty. Details with numerical values such as gear and diff ratios can be used in maths expressions.

Corrected Speed and Distance

Use fastest of 2 channels

or use first available from this list

Apply Long G correction
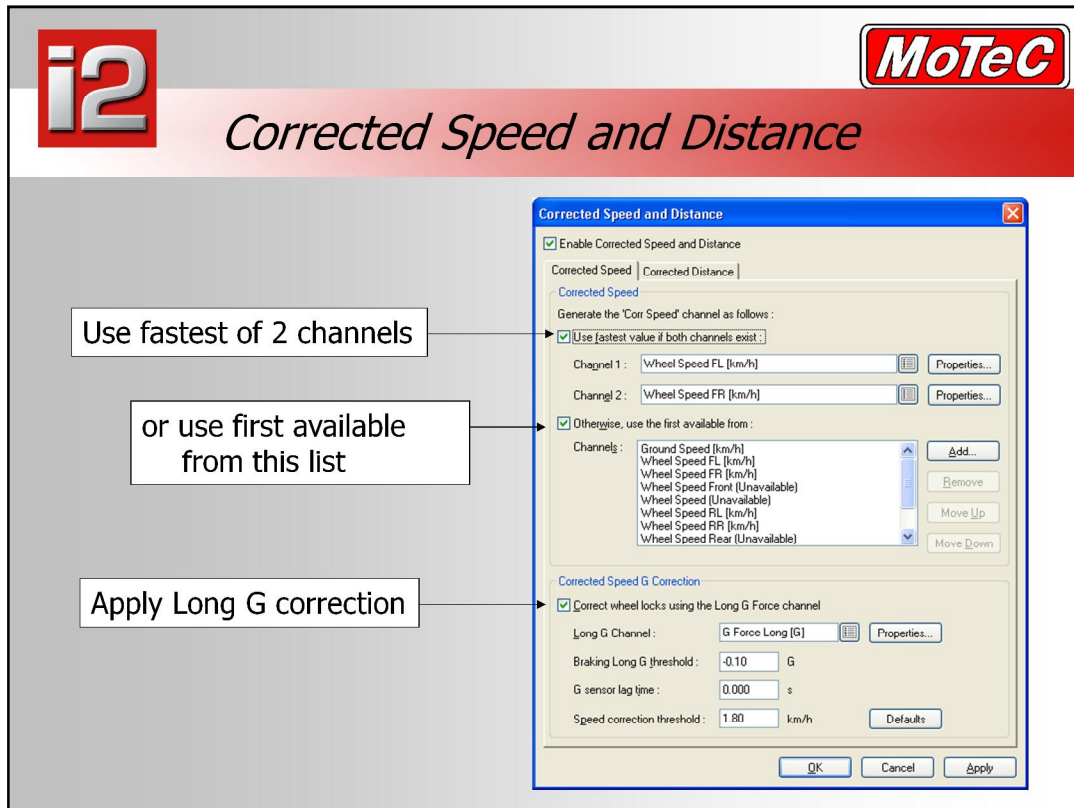
- Although distance is generally calculated in the SDL/ADL2, i2 also performs a distance calculation to give what is known as 'corrected distance'. Corrected Distance must be calculated so that the graphs can be plotted against distance rather than time. This allows laps to be compared at the same distance point on the track – the only way to make a meaningful comparison. To ensure that the distance is as accurate as possible, there is an option to calculate a 'Corrected Speed' channel from one or 2 input channels, along with Longitudinal G correction to account for wheel lifts or lock ups.

- Setup for Corrected Speed is under the 'Tools' menu.

- By default Corrected Distance is calculated from Corrected Speed, however another speed channel can be selected as the input to this calculation. To account for variations in the measured speed and resulting distance from one lap to another, lap lengths are stretched to match the track length. This allows for consistent comparisons across different laps and sessions.

- On the "Corrected Distance" tab there is a button labeled "Report" Click this button to show the distance report of all laps. This report show lap stretch or shrink to allow for slight lap length differences from lap to lap. You can turn this on or off in the previous screen, as well as set the maximum stretch/shrink percentage.

Comparing Laps – Overlays
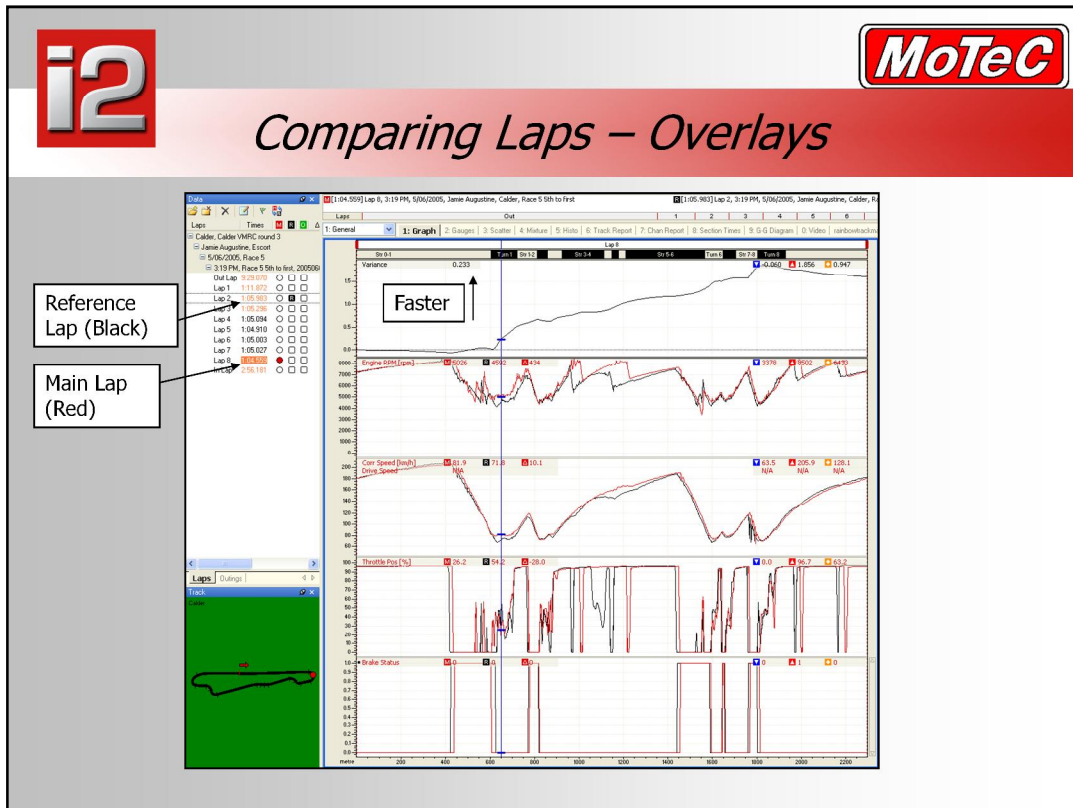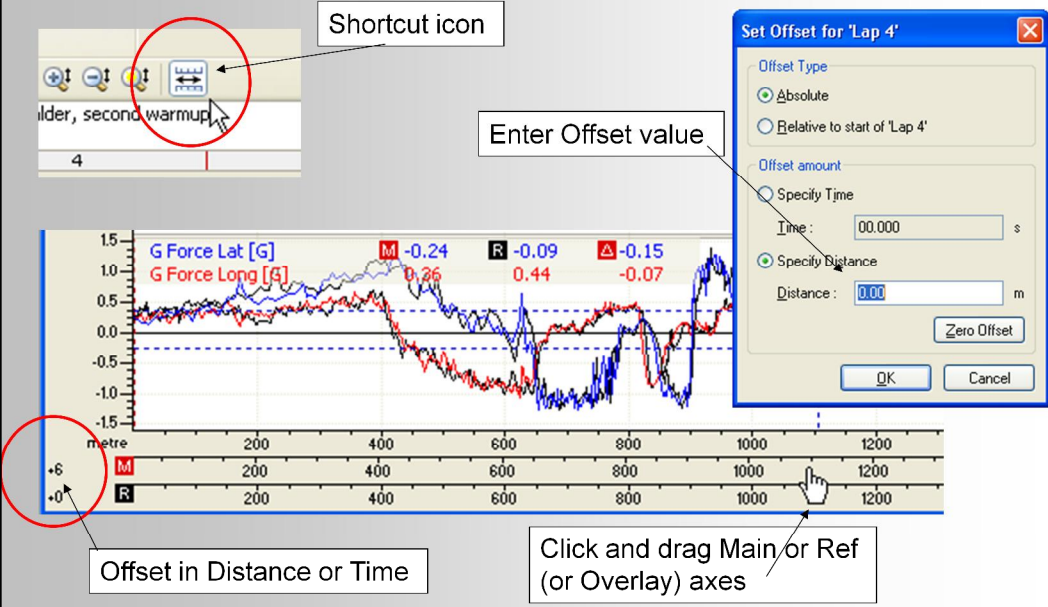
- Comparing two laps is one of the best ways to find places where your car or driver can improve. Using two laps of data, select one as the Main lap, and the other as the reference lap. When you do this, it puts the overlayed data in black (colour can be changed) along side the Main data. One thing to remember when overlaying laps is to always do it in distance mode, not time. The reason for this is that if you are comparing two laps, the track distance will be the same lap to lap, so your speed, throttle, pressure and other readings are compared at the same points on the track. If you try to compare the data using time, as you lose time over the lap, the traces become no longer aligned, offset by the amount that one lap is slower than the other.

- By pressing F3, you can insert a variance trace at the top of the worksheet as shown above. As you can see, the variance line shows where one lap has gained or lost time over the other lap. This is a useful trace to find the points on the track where the most time has been gained or lost, showing the driver what part of the track to focus on to make gains in time. As a starting point look for the steepest slope or biggest jump in the variance line, then zoom in on that area of data.

1. **Press "1" to select the first worksheet, "Graph".**
2. **Press F8, and select lap 2 (1:03.682) from the Calder, i2 data day file from 9:53am in the main column**
3. **Select lap 3, (1:05.19) in the reference "R" column, then click on the graph to hide the data flyout.**
4. **Press "F3" to toggle variance on and off.**

Offset Axes

- In some instances you may be comparing data from different sessions where the beacon has been moved. In this case it becomes necessary to offset one lap relative to another. This can be achieved using the 'Offset Axis' feature of i2.

- To allow precise alignment of main and reference each may be offset in time or distance. This is done by turning on the offset axis by selecting Show Offset Axis from the graph component menu or by pressing the O key.

- This shows an axis for the main and reference below the nominal axis, which allows either one to be dragged relative to the nominal axis. Dragging can be performed using the mouse or by using the keyboard shortcuts: Ctrl+Shift+Arrows to move the main lap or Alt+Shift+Arrows to move the reference lap. Offsetting may be turned off by pressing the O key again, this will also zero the offsets for the main & reference lap. Normally offsetting is used to make small corrections to allow for slight difference in the distance calculation from lap to lap. The best way to align laps it to look at bumps in the track surface using either the vertical G channel or a suspension position channel.

- An offset can also be entered in seconds or meters by right clicking on an offset axis and selecting 'Set Offset'.

1. **Press "O" to show the offset axis**
2. **Click and hold on either the "M" or "R" axis, and drag it around to line up the data.**
3. **Remember to be in distance mode for overlays (F9)**

Where did I lose time?
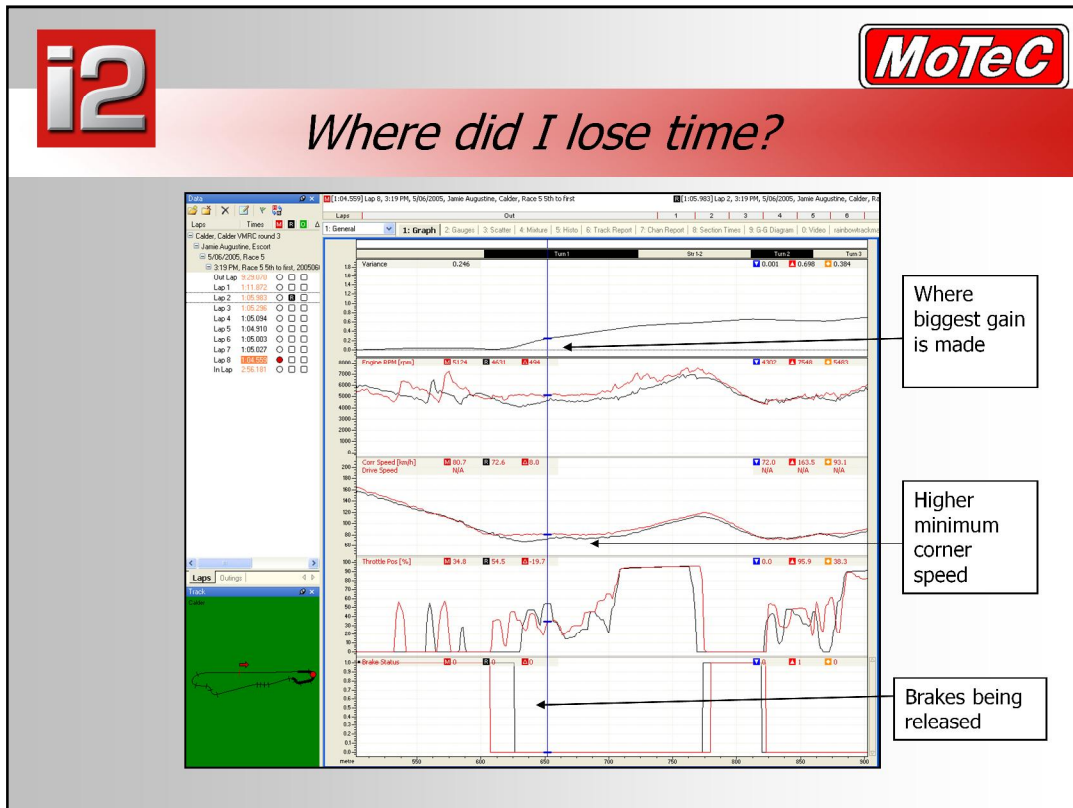
- Ok, now we have zoomed in to the part of the lap where the most time was lost on these two laps. What is apparent here is that the minimum corner speed of the red line car through turn 1 at Calder is up to 13km/h higher than the black line car. You can see how this happened when you look at some of the other sensor traces. Looking at the "brake status" first, during the faster lap the driver was off the brakes earlier at the end of the braking area, and then on the throttle earlier, but noticeably hit full throttle at exactly the same point on the track – but had more part throttle earlier through the turn.

- This braking difference and holding corner speed was worth a half second in the overall lap time of the vehicle.

- There is a lot to be said for knowing where time is gained and lost when we are talking about differences like this.

- Better drivers will have much smaller differences lap to lap, and much smaller gains, but the process is the same.

Global Maths

- Global maths is calculated for all log files that are loaded. Global maths is stored in maths files within the project. Multiple maths files can be used, which allows the maths to be separated into functional areas such as Engine, Chassis, Aero etc. The global maths files may be copied to other projects by clicking on the Import and Export buttons in the Maths Editor. An example of maths that may be useful as global is a Lateral G filter that you always apply to your car to give your data a comparable trace.

Local Maths (Maths per log file)

- Maths may also be created per log file. The local maths is stored along side the log file in the companion (.ldx) file, the original file is never modified. This would normally be used for things such as setting the steering trace to 0 if you had forgotten to do so before the session.

Order of Calculation

- The order of the maths equations in the list does not mater. Any dependencies are determined at calculation time so that if a maths equation requires other maths channels then the required maths channels will be calculated first.

On Demand Processing

- The maths equations are processed on demand. i.e. as different worksheets are displayed the required maths channels will be calculated as the worksheet is displayed (unless they have already been calculated).

Maths Status

- The status of the maths calculations is available in the Tools | Channel Status dialog. Note that any maths channels that have not been displayed or otherwise required will be tagged as Pending due to the "on demand" processing scheme.

Constants

- Constants are used to represent common factors such as Pi. Maths Constants are stored in the maths files and can only be accessed by maths within that file.
- Maths File constants are specified in the Maths Expression Editor.

Maths Expressions 1

Example

An expression that creates vehicle acceleration can be described as follows:

Vehicle Acceleration = derivative (Wheel Speed)

The resultant value of this equation depends on the units specified for wheel speed which must be specified in the equation.

In this example it is easiest to use units that have a corresponding speed and acceleration equivalent as this avoids the need for conversion factors, for example m/s for speed and m/s/s for acceleration.

So the equation could be entered as follow:

Channel Quantity: Acceleration
Display Units: G (or any other valid unit)
Expression Result Units: m/s/s
Expression: derivative ('Wheel Speed Front Left'[m/s])

Expression :

derivative('**Wheel Speed FL**'[m/s])

This will work irrespective of the units that the wheel speed was logged in and irrespective of the units the result is to be displayed in. For example wheel speed may have been logged in mph so the maths will convert mph to m/s before differentiating which will give a resultant value in m/s/s. By telling the system the units of the resultant value is m/s/s the resultant channel can be displayed in any units we like which in this case would typically be G.

This means that maths that has been written in metric or imperial will work correctly irrespective of whether the user chooses to log in metric or imperial and irrespective of whether the user chooses to display channels in metric or imperial.

- Maths Expressions are powerful maths formulas that are entered in plain text format.

Channel Names used in Expressions

- When entering channel names into an expression all channel names must be enclosed in single quotes, for example: 'Engine RPM'. The quotes are added automatically if selecting a channel from the embedded channel list. Channel names are not case sensitive so 'Engine RPM' could also be entered as 'engine rpm'

Units of Channels used in Expressions

- When entering an expression every channel should be followed by units in square brackets. For example: 'Wheel Speed Front Left' [km/h]

- The units specified are the units that the channel value is converted to before the calculation is performed and thus affects the resultant number and the appropriate result units (see below).

- Note that when a channel is selected from the channel list the default units will be automatically appended to the channel name. If the units are not the desired units then they may be edited as necessary. When typing the units a help window will show the valid units for the particular channel.

Maths Functions

- An extensive set of maths functions is provided for use in the expressions.

- For details on the available maths functions and associated parameters see: Maths Functions

Result Units

- The result units of the expression must match the numeric result of the expression.

- Note that the result units need not be the same as the display units. It is very important to understand this difference.

Maths Expressions 2

Type Maths Expression
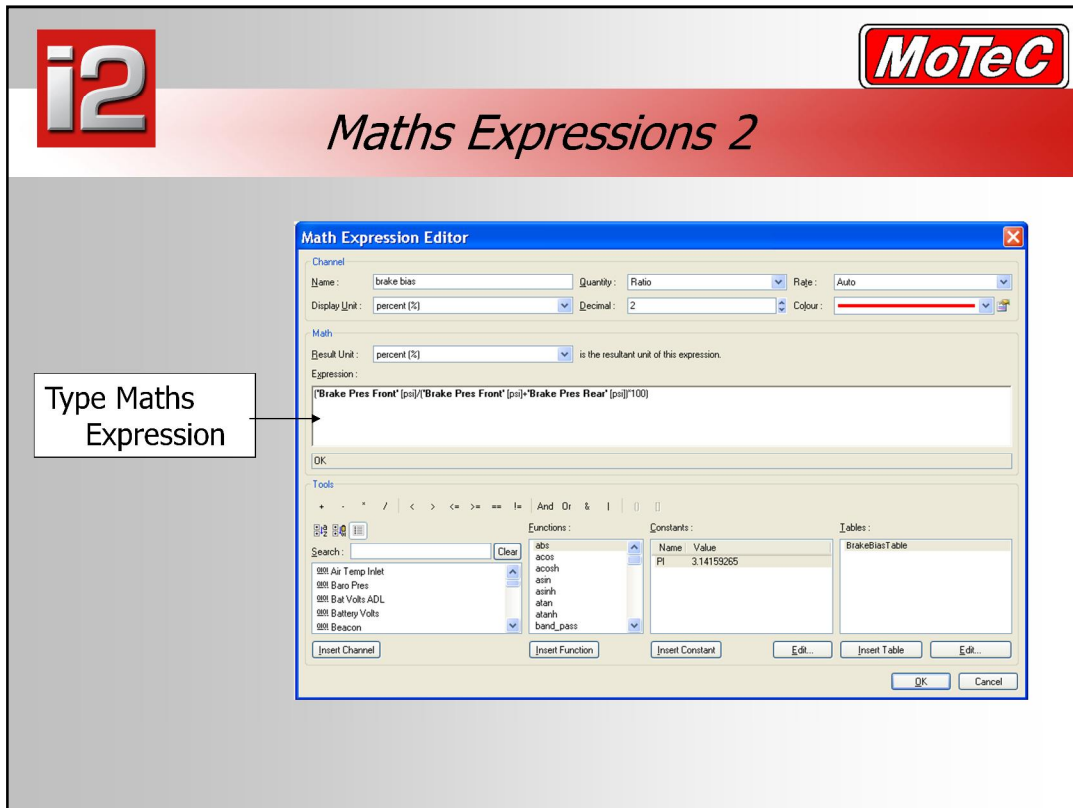
Maths Channel Name

- The name of the resulting maths channel is specified in the expression editor.
- The maths channel name may contain any character except single quote (').

Sample Rate

- The sample rate specifies the sample rate of the resultant maths channel.
- If the channels used in the expression do not have the same sample rate then they will be re-sampled to the result sample rate before the maths expression is run. The re-sampling function uses linear interpolation to determine the values at the new sample rate. It is normally best to use a sample rate that is equal to the highest sample rate of the maths input channel(s).
- **Auto Sample Rate**: The Auto sample rate selects the highest sample rate of the input channels and therefore suitable for most maths processing.
- **Quantity** : The quantity must be set so that valid display and result units can be set.
- **Display Units, Decimal Places, Colour**: Sets the default values for these channel properties.

1. **Enter this expression for Brake Bias Calculated:**
    'Brake Pres front' [psi] / ('Brake Pres front' [psi] + 'Brake Pres Rear' [psi])
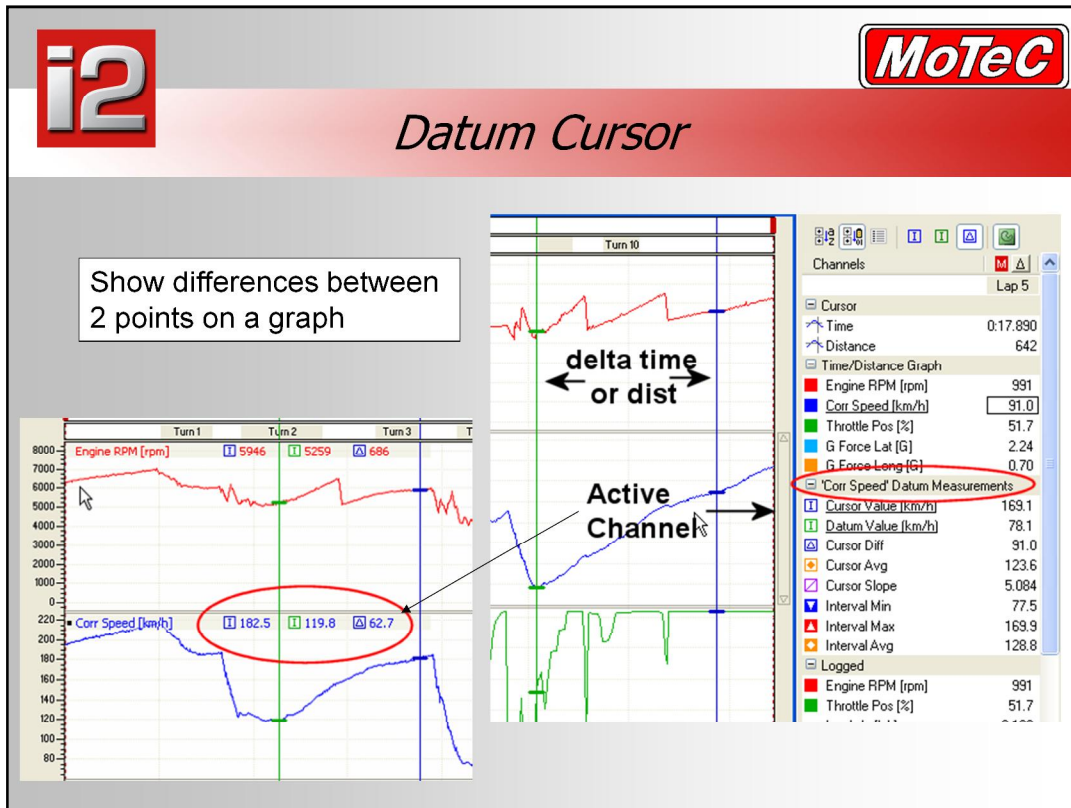
- The datum cursor is a second cursor that allows measurements to be made between two points. To place the datum cursor, position the main cursor to the point of interest then press the 'Space Bar' key then move the main cursor as normal. The graph labels now show the values of each channel at the datum cursor, main cursor and the difference between the 2 values.

- In addition to this, there are Datum Measurements in the cursor window for the currently active channel. The active channel is denoted by the vertical scroll bar next to that trace, by the channel value having a box around, and the channel name is given in the 'Datum Measurements' area.

Measurements:

- ΔTime   time difference between the cursors
- ΔDistance   distance difference between the cursors
- Cursor Value   channel value at main cursor
- Datum Value   channel value at datum cursor
- Cursor Diff   channel difference between 2 cursors
- Cursor Avg   average of the 2 cursor positions
- Cursor Slope   rate of change between the 2 cursor positions (gradient)
- Interval Min   min channel value b/w cursors
- Interval Max   max channel value b/w cursors
- Interval Avg   average of all points between the cursors

Keyboard shortcuts:

- 'D'   toggle datum mode (& cursor) on/off
- 'X'   swap positions of main and datum cursors
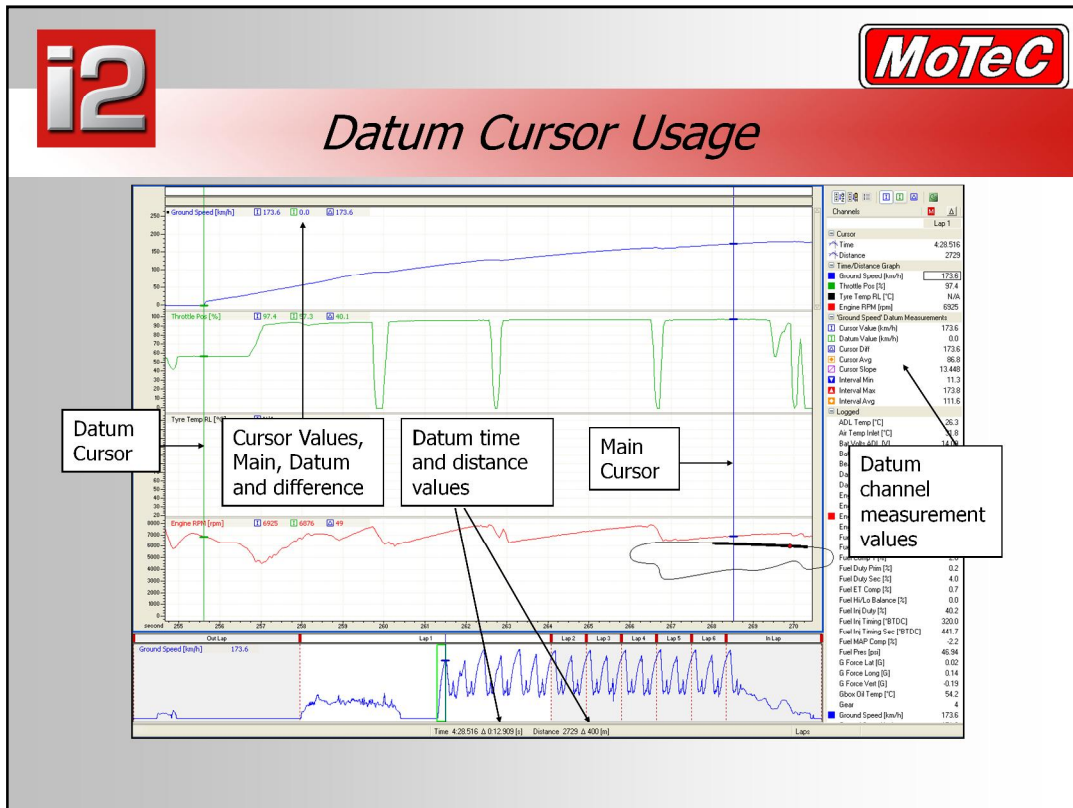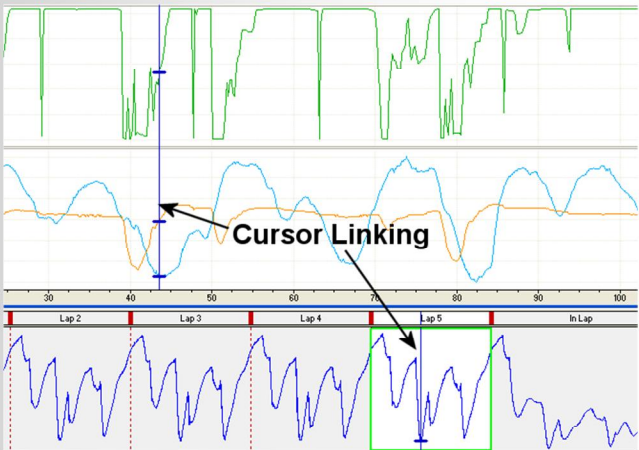
Datum Cursor Usage

- Datum Cursors are an efficient way to measure the change in a channel across a period of either time or distance. Common uses of this include measuring the starting performance of a car (0-100km/h, ¼ mile etc), measuring temperature change across a period, RPM rate of change in each gear and much more.

- The above example shows the car leaving the line where the green Datum cursor has been placed. The Main cursor has been placed at 400m, giving the ¼ mile time for this car. In the panel on the right, you can see the statistics for the selected channel between these two cursor points. Here you can see that the car reached 173km/h at 400m, average speed of 86.8km/h with an average rate of change across the period of 13.448km/h per second.

1. **Press "F8" to bring out the data flyout, and turn off your reference lap if you have one by clicking on the black "O" in column 2.**
2. **Select the main lap to be Calder VMRC Round 3 05/06/2005, Race 5, 3:19pm lap 8 1:04.559**
3. **Press F2 to show the whole outing.**
4. **Press F9 to show the data in time mode, and place the cursor at -7:48.923**
5. **Press Space bar to place the datum cursor, then place the cursor 400m later at –7:36.001**

- Linking: By default the cursor is linked across all worksheets and books. Also, display components are also 'zoom linked' across work book/sheets. This way you can change the zoom level on one sheet and then see the same data section on another sheet.
  To change this, go to the particular display element properties (F5) and under "Mode - Link Options" uncheck the box "Cursor linked". The cursor will now be 'local' for that item.

- **Gating -** The gating channel allows data to be rejected based on the value of a channel. Data is rejected if the channel value is less than or equal to zero. The gating channel is normally generated by a maths expression. For example a maths channel defined as abs('G Force Lat') > 0.5 would result in a value of 1 during corners and 0 during straights and would therefore reject any data in straights. Gating can be used with Scatter Plots, Mixture Maps, Histograms and Suspension Histograms, with the same or a different gating expression for each. This is simmilar to how you can turn on and off trace colors in a histogram.

- **Setup Sheets -** Allows the user to import a list of values relevant to a particular session. eg: Corner weights, Spring Rates, Tire pressures. As well as being linked to the relevant log file, the data can be used in maths expressions.

- **User Sections -** In addition to modifying the auto created sections, users can define a new section category and define sections from scratch, eg: track sectors. These can then be used in channel reports, track reports and time reports.

- **Alias Editor -** allows a channel to be created that will use the data from the first available channel in the corresponding alias list. This can be useful if the name of a channel varies between log files. For example an alias channel could be created called Vehicle Speed that uses either Ground Speed, Wheel Speed FL or Wheel Speed FR. Note that the first available channel is used so the order of the list can be important.

- **Channel Mapping - a**llows a channel to be renamed and/or the units of a channel to be overridden. This can be useful if a channel is named differently in some log files. It is also useful for channels that were logged without units (for example a Wheel Speed from an ECU).

Slide content:

Temperatures

Air Temp Inlet [°C] — 37.2
Engine Temp [°C] — 78.0
Gbox Oil Temp [°C] — 45.9
Eng Oil Temp [°C] — 45.3
ADL Temp [°C] — 25.2

Ground Speed [km/h] — 0.0

Max Engine Temp

The maximum temps for each channel by lap

Channel Report - All Laps

		Lap 1	Lap 2	Lap 3	Lap 4	Lap 5	Lap 6
ADL Temp [°C]	Max	27.3	27.6	27.7	27.8	27.9	28.1
Air Temp Inlet [°C]	Max	37.4	22.3	20.9	20.6	21.1	20.8
Eng Oil Temp [°C]	Max	94.7	100.6	105.0	108.5	111.0	113.3
Engine Temp [°C]	Max	103.5	83.3	80.5	81.3	81.6	81.6
Gbox Oil Temp [°C]	Max	69.9	74.1	77.5	80.2	82.7	84.2

- Reading temperatures is a similar process to the reading the throttle trace. If we look at the engine temperature trace, we can see that it started at around 80 degrees, and fluctuated up and down for a while. At around –250 seconds (from the start of the selected lap) we can see that the temperature peaks at over 100degrees. It is important to consider for what reason are you looking at the temperature. Are you looking for peak temperature to decide if a thermo fan is required for times on the grid or as the car cools down at the end? Perhaps you are looking at racing laps only, so that you can see if there is sufficient cooling during a race situation. The answer to this determines where and how you should be looking at the data.

- If you are keeping a log of maximum temperatures that an engine has reached, it is usually best to look at peak racing temperature rather than a stationary temperature. Don't be fooled by maximum outing temperatures in the channel report, you can see above, that it has reported that the maximum engine temp reported is 103.5. This number isn't an indication of the cooling ability of the car, more a representation on how long the starter held the car on the grid.

1. **Select workbook "User" Add new worksheet "Temps"**

2. **Add time/distance graph, cancel out of properties window. and press C to bring up channel window then type in "temp"**

3. **Double click on all temperature channels to add them to the graph. Also search for ground speed and add it to the graph**

4. **Remember to click on the overlay lap in the data window to remove the overlayed lap if it is still active**

5. **Press F5 to open the channel properties window, and regroup the temps into logical sections, tires, brakes etc**

6. **Press F2 to look at the temperatures across the whole session.**

Pressure summary per lap.
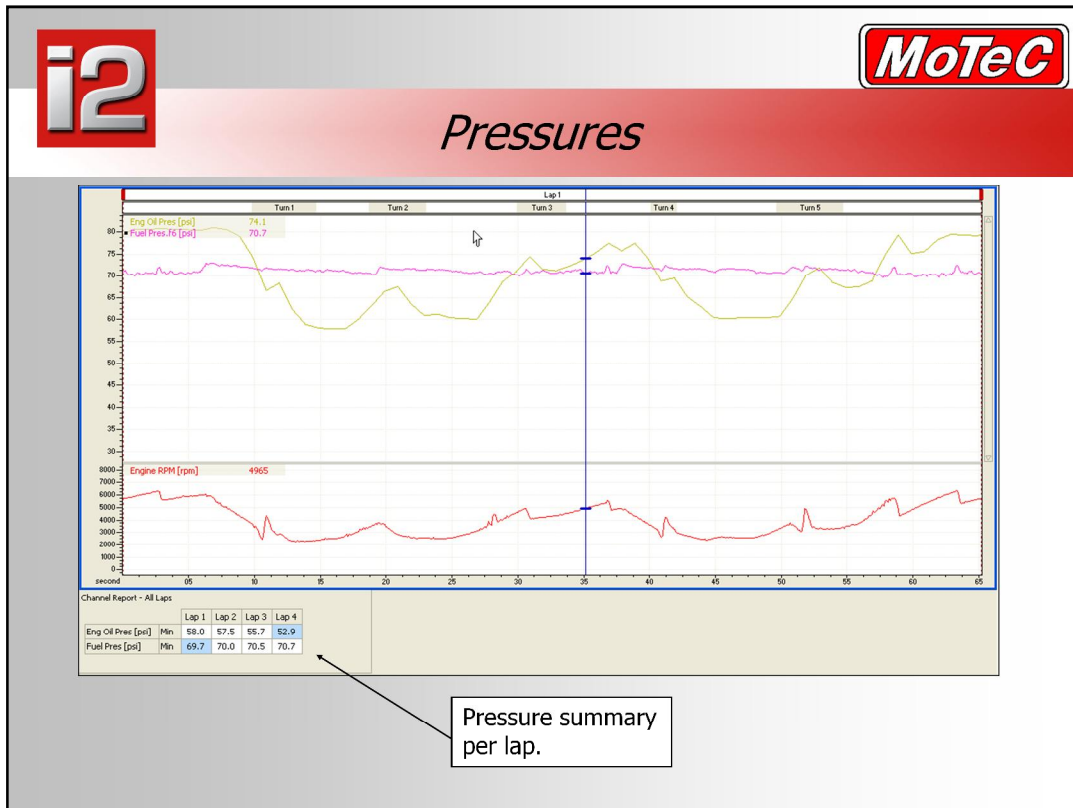
- Pressure traces are often vital in examining the health of your vehicle. Whether it be fuel, oil, brake, manifold or other pressure, checking these values after each outing is an important part of ensuring that the vehicle is running well. To read the traces, again from the left, you can see the pink trace, fuel pressure, starts at 72psi, and bounces up and down with pressure pulses across the lap. Engine oil pressure starts at 80psi, then rises and falls in line with engine RPM. You can also examine just how much oil pressure your engine is losing with oil temperature increase over the length of the outing.

- Below the time/distance graph, you can see a channel report of the two pressure channels displayed. The blue shaded numbers are the minimum pressure values for that lap, but you can also choose to show maximum, and/or average.

- It is very common to see very noisy fuel pressure readings, although sometimes it is believed that the noise is the logger or the sensor. Looking at fuel pressure data from even highly developed race engines, it is common to see fluctuations of 10-15psi when a good sensor is used. Don't assume that the noise isn't a genuine indication of the pressure that is happening in the fuel rail, it is more likely to be the actual fuel pressure pulse waves than sensor noise. These pressure waves are often dependant on injector duty cycle.

- There are different types of pressure sensors, some less expensive than others. So consider just how accurate you want your reading to be when you decide what you should be using.

1. **Select the "User" workbook, and add a new worksheet called "pressures", placing a Time Distance graph on the sheet.**
2. **Press "C" to select the channels flyout and type in "Pres" to see a list of all pressures, adding double clicking on oil and fuel pressure to add to the sheet.**
3. **Next select engine RPM and add it to the time distance graph.**

G force long and lateral along side braking and throttle
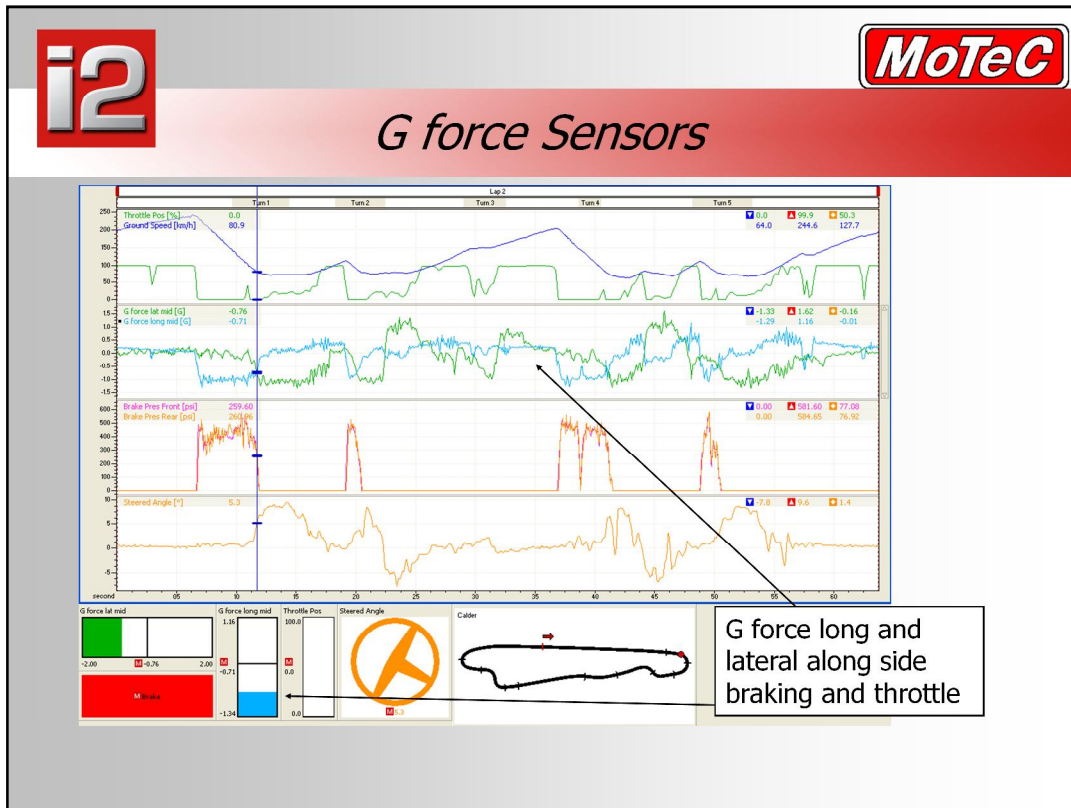
What is an accelerometer?

- An accelerometer or G force sensor measures the forces being applied to the car. These forces include acceleration, braking, cornering in both directions, up and down. To understand what they are measuring, imagine a bob weight being hung from the roof of a race car, as you accelerate, it swings backwards, as you brake, it swings foreword. The distance of the bob swing represents how much force there is in that direction. A G sensor measures this force, and the data logger gives a value proportional to the force of gravity, hence 'G' sensor.

What can I get from a 3 axis accelerometer?

- 3 axis accelerometers allow the user to measure and record the acceleration of a vehicle in three dimensions. By combining the information from all three accelerometer axes it is possible to calculate the resultant overall acceleration in three dimensions.

- Accelerometers allow the user to perform fundamental operations, for example obtaining a track map or studying the balance of the car in terms of understeer and oversteer. They also permit more complex calculations, for example computation of the weight transfer the car experiences during braking, acceleration or turning phases.

- It is extremely useful to use the G sensor to compare braking forces and technique in overlay mode. You can see how hard the initial deceleration is, and verify that the braking is hard, right into the corner, not tapering off at the end. You can also see how consistent the pads are, you could compare a brake fluid line pressure to a deceleration force to look for fade in the braking system.

- They can also be used to compare how much lateral traction a given tyre/track/suspension setting is able to obtain, then compared to another lap to see how your changes have affected vehicle cornering grip.

1. **Add a new worksheet in the User Workbook called "Forces" and add a time distance graph to it.**

2. **Turn off any reference lap that you may have selected and choose lap 2 (1:03.682) from the file Calder i2 day, 23/11/05, 9:53am.**

3. **Add channels Brake pressure front and rear, G force lat, long and Vert, Ground speed, Throttle position and Steered angle.**
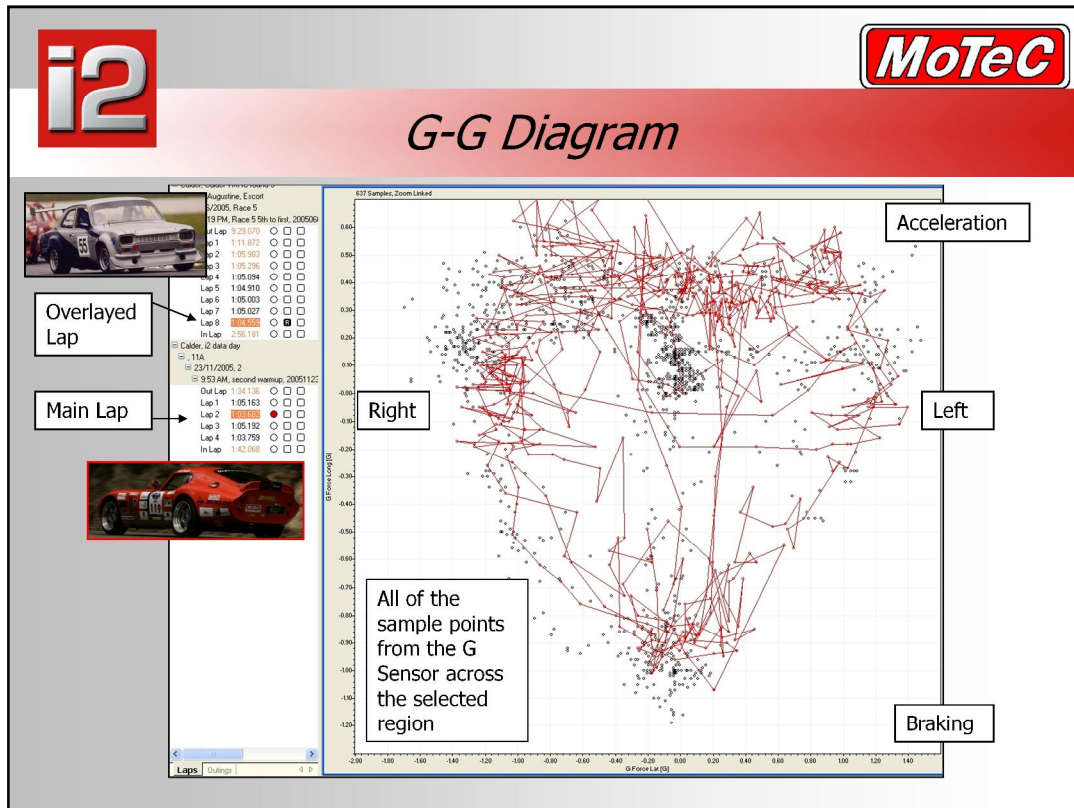
- The G-G diagram is a conceptual way of showing the performance of a driver, vehicle and circuit together. This method of measuring performance has been around since the late 50s with the first methods of creating these diagrams using a two axis pen recorder.

- In theory, the driver should try to operate as close to the boundary of the G-G circle as possible at all times. In reality, physical limitations prevent a vehicle reaching the theoretical boundary (e.g. changes in suspension geometry, brake balance, tire grip, etc). The more the driver can push out the envelope of the plot to the ideal circle, the better use he/she is making of the available grip of the tires and the available grip of the track.

- But what is the limit of the vehicle, or the limit with a perfect driver? A G-G diagram is useful as a comparison tool.

- Take the example above, the red data is fastest lap from the Daytona Sample file, the overlayed lap is the fastest lap of the Escort sample file. From this example we can see that although the lap times are less than 1 second different, the plots show very different characteristics of the two cars. The Black data is out further to the left and the right, showing more cornering forces from the Escort compared to the Daytona. The Escort also shows more samples in the braking area, up to 1.2G deceleration, with the Daytona reaching only just over 1g from a far heavier vehicle. The obvious place where the Daytona is better is up the top of the G-G diagram, showing consistently greater acceleration. Now this example is comparing two different types of car, but it shows how you can overlay different drivers, in the same car and learn how, and why one driver is different than another in the way they extract speed from a car.

- The best way to obtain high quality data is to use a 3-axis accelerometer mounted at or below the centre of gravity. We recommend mounting the sensor on Velcro or alike to isolate the vibration in the car from the forces applied to the vehicle itself that we really want to measure.

Brake pressures and temps shown both on graph and as gauges for clarity.
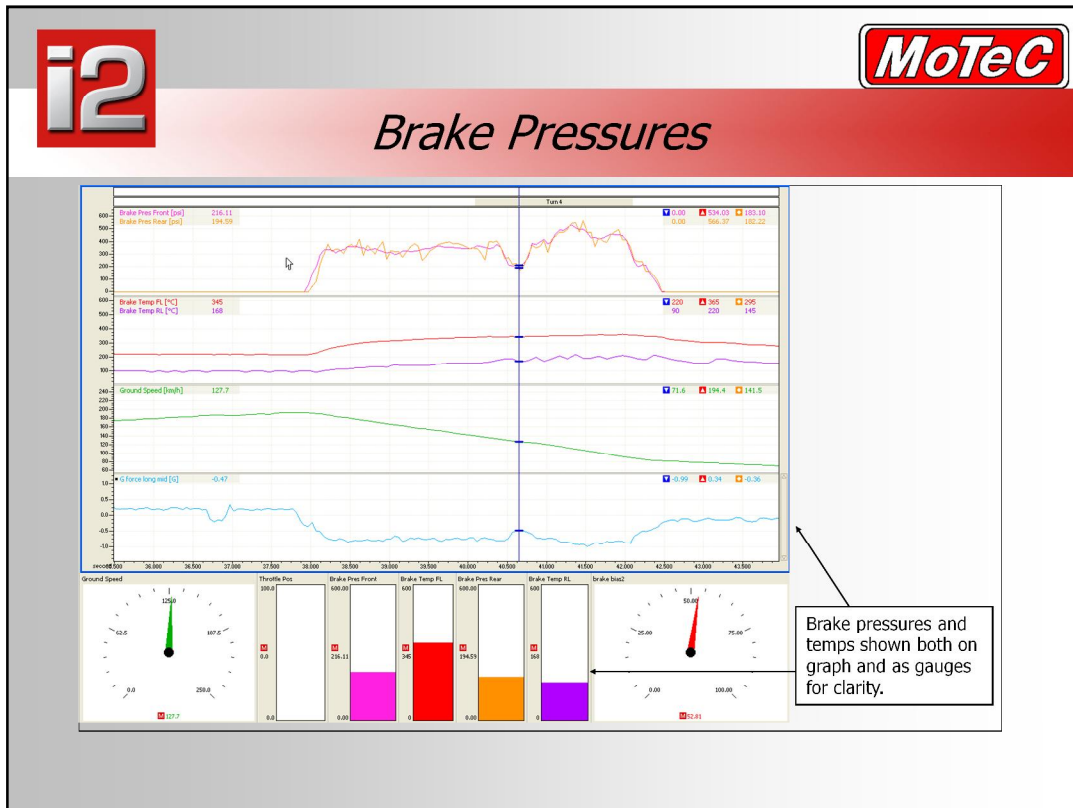
- When it comes to fine-tuning a racecar to improve its performance around the track, many people focus on the horsepower delivered by the engine and the handling characteristics in corners. In fact, the brakes are going to have a significant effect on lap time, as well as lap-to-lap consistency and driving ease. Fine tuning the brakes allows us to exploit more efficiently the grip available under each wheel to minimize the braking distance and facilitate overtaking maneuvers during the race. The right brake bias setting will also reduce the risk of flat spotting the tires, and make the car easier to drive. One of the most effective tools to monitor the brakes are two brake hydraulic pressure sensors – front and rear. This type of measurement will allow you to understand how your brake system is being used and help the driver to evaluate its performance after a session.

- Often, a better braking system can make the little difference at the end of the straight that allows overtaking another car. As in any other hydraulic system, knowing the pressure of the fluid circulating is going to help you to monitor the different forces applied in each of the devices connected. Moreover, the driver can make progress in his driving style: comparing his braking point lap after lap, the intensity of his braking and his quickness on the pedal.
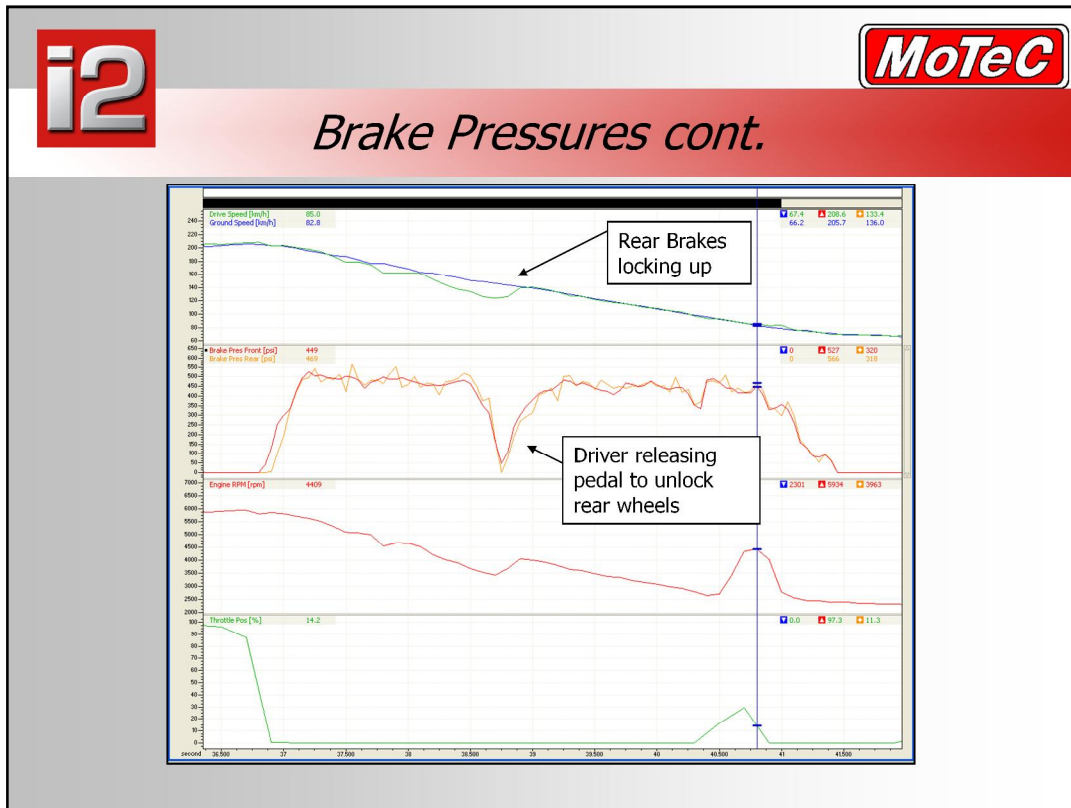
- It may seem obvious, but looking at the brake pressure traces gives you the time at which the driver started to brake. This information is very important, as a few meters difference in braking are very important for the speed you carry through the corner, and the time you gain or lose. Once again, looking at these traces with an overlay between two laps will permit you to perform a quick and efficient analysis of driver style and consistency.

- Be careful with the logging rate used for those channels. If it's 10Hz for example, the system will record one value each tenth of a second. And at the end of the straight, at 250 km/h, the car is traveling 7 meters in one tenth of a second. So before concluding that driver A brakes 21 meters later than driver B at the end of the straight, check if your logging rate needs to be increased.

- Directly measuring the pressures in the Front and Rear brake systems allows you to know how the driver is braking. In effect, both the shape and the amplitude of the brake pressure traces are very important for optimum braking. Most of the time, you want the maximum deceleration (indicative of late braking) to reach the maximum speed in the corner without losing speed in corner entry and being able to carry the maximum speed in corner exit.

- The shape of the optimum trace can be explained by:
  - Having the maximum deceleration in corner entry
  - Losing the minimum time and speed in corner entry
  - Releasing the pedal progressively and gently while turning

- Braking hard at the beginning (by literally jumping on the pedal) will be shown as bigger pitch acceleration.

Braking – heel and toe
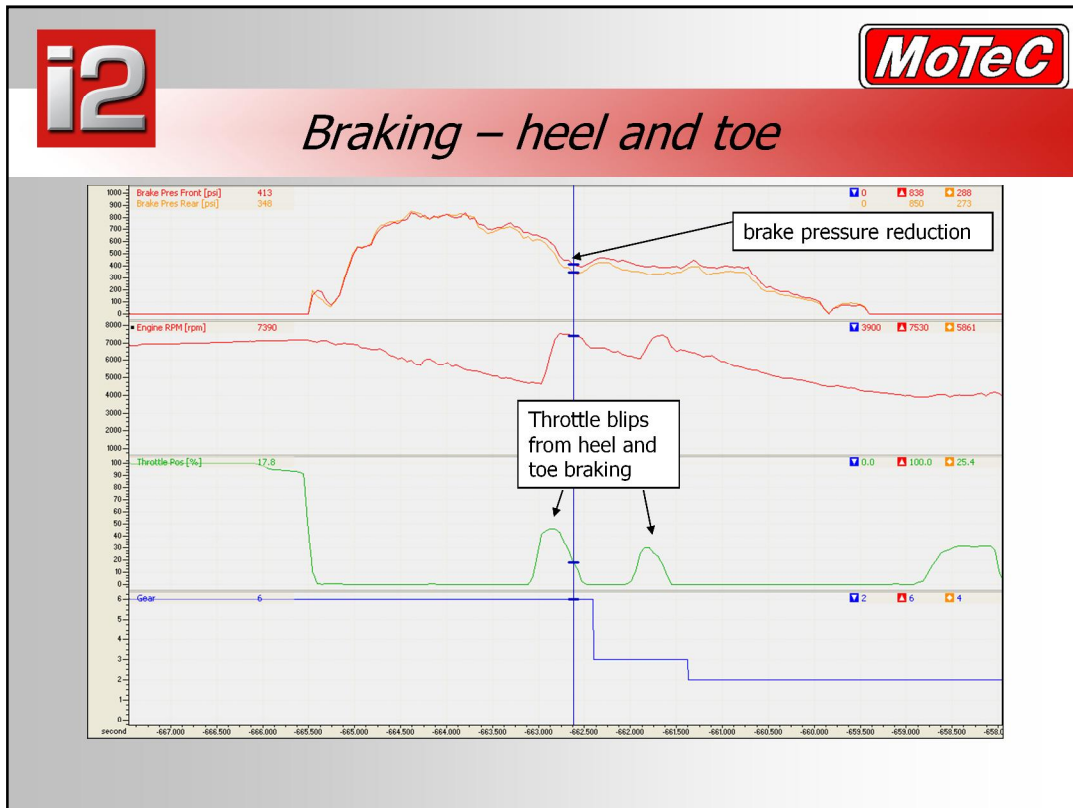
How much does he lose in heel-toe braking?

- In a braking zone where the driver downshifts gears, it is always interesting to look at what happens to the brake pressure during that time.

- We can clearly see that each time the driver downshifts, he is adding a small amount of throttle, and because he is doing that the brake pressure diminishes slightly. As this ends up being time lost under brakes, the goal here is to lose the minimum of braking pressure while downshifting. It is possible to monitor the driver's progress on this issue using brake pressure sensor.

The steering trace can be visualised by displaying it as a gauge.
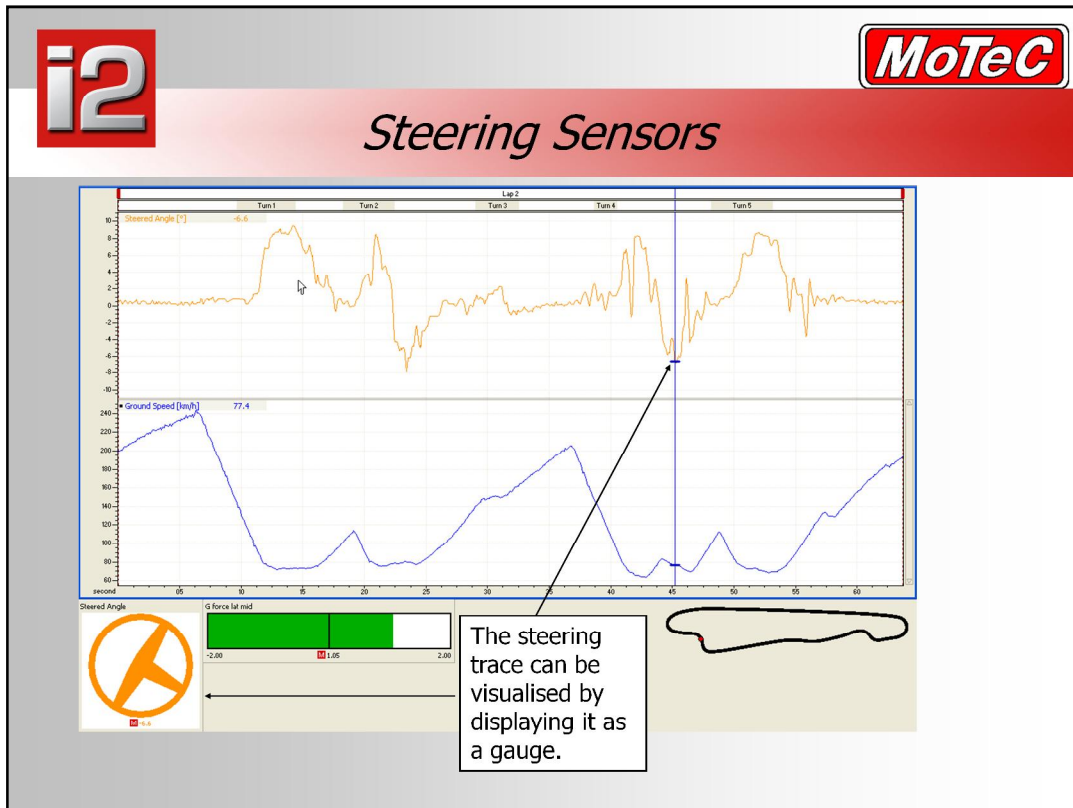
- Steering position sensors are used to measure the angle of the steering wheel or the front wheels while travelling around the racetrack. This sensor is primarily used to visualize how the driver is actuating the steering wheel. Whenever the driver is correcting an understeer tendency, or negotiating oversteer, the exact movement will appear on the data at the exact place it happened on the track. Thus, it is an extremely useful tool for correlating the feel or handling reported by the driver with the data recorded by the data logging system.

What Can I Learn From My Steering Sensor?

- The way a driver uses the steering wheel is fundamental to the quality of a racing lap. Examining the smoothness or aggressiveness of the drivers input through the steering wheel can be very helpful for analysing the driving style of a driver. By following the graph of steering wheel angle at positions along the track, it is very easy to correlate the information given by the driver about oversteer and understeer. Usually the driver can tell pretty well where he/she has balance problems However, if you ask a driver if it worse in turn 5 or turn 3, or if he/she lost more time because of the oversteer at the exit of turn 4 or the understeer at the entry of turn 7, they find it a bit harder to answer. It is precisely at that point that the data acquisition system will bring an advantage.

More Steering

Below is a graph of two steering traces for two identical laps of an oval track, one at very high speed (in Black) and the other at very low speed (in Red).
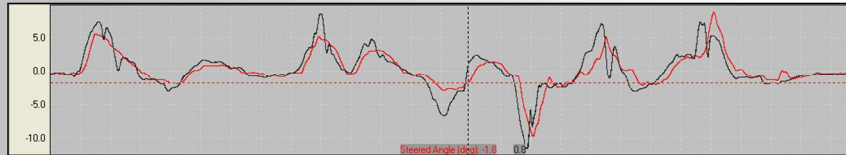
- Examining these traces, you can see that they are no longer matched to each other, even though they are both for the same car around the same line on the same track.

  To keep the car on the same trajectory the driver will have to steer more or less depending on the slip angle of the vehicle. So where you see the fast lap steering angle exceeding the slow lap one, this is showing understeer.

- If oversteer occurs, larger slip angles will be generated at the rear tyres. Hence to keep the car on the same trajectory the driver will have to steer less.

- Comparing the steering trace at high and low speed will help us to quantify the understeer or oversteer only if the driver is as accurate as possible at keeping to the same trajectory during both runs.

- Above is a technique suggested by Claude Rouelle of OptimumG. The trace from a lap carried out at lap speed should be on the normal drive line, but slow enough to minimise slip, thus giving data as close as possible to neutral steer on that circuit.
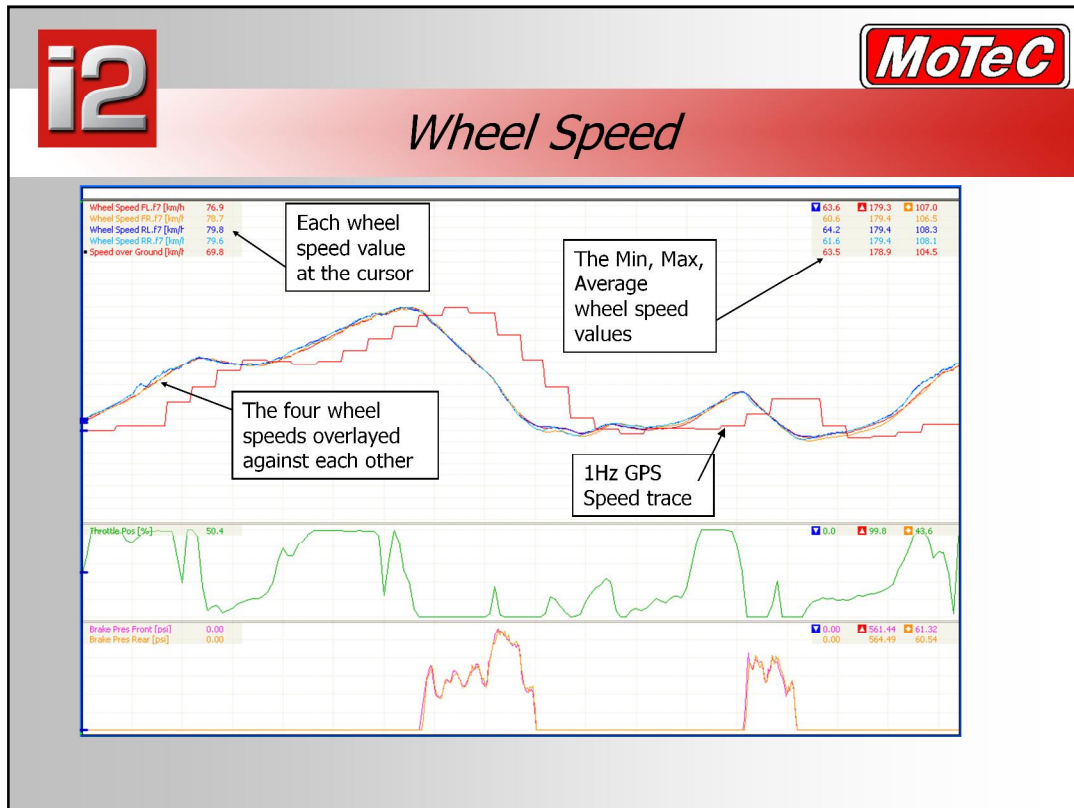
- The wheel speed sensor is one of the first sensors that you get with a data acquisition system. Beside speed computation, this sensor will allow you to:
  - Compare the speed of drivers or of cars, lap by lap
  - Detect where time is lost or gained
  - Detect wheel lock under braking
  - Detect wheel spin due to overpower
  - Draw a track map on your screen
  - Gear detection (also requires Engine RPM)
- Moreover, following some more advanced computation, it is possible to evaluate the differential work efficiency, or the slip ratio your tires are working at. In some cars, those sensors are going to be part of the systems managing traction control, ABS or vehicle dynamic stability programs.
- Above you can see all wheel speeds directly determined by sensors on each wheel, overlayed against each other. The red trace shows a 1Hz GPS speed trace sampled at 10hz (over sampled). It is interesting to note that while the GPS speed over ground trace does give a reasonable idea of speed, it is very slow in response, and seems to have a delay of over 1 second compared to the actual wheel speed sensors. This is due to the time that the GPS takes to read and process the satellite updates. Compare this to newer 5,10 and 20Hz GPS units now available which are very accurate.

1. Select file 'Calder,i2 Data Day' and Lap 2, 1:03.682

2. Add a new worksheet called "Speeds" in the workbook "User"

3. Add a time distance graph to the sheet

4. Add channels wheel speed front left, right rear left and right.

5. Add brake pressures and throttle position also to the graph.

6. Filter all 4 wheel speeds over 7 samples by right clicking on each channel label, select filter, then type "7" into the samples box, then click "ok".

Wheel Lockup

In this slide, you can see where the rear right wheel speed drops significantly below the speed of the front wheels.
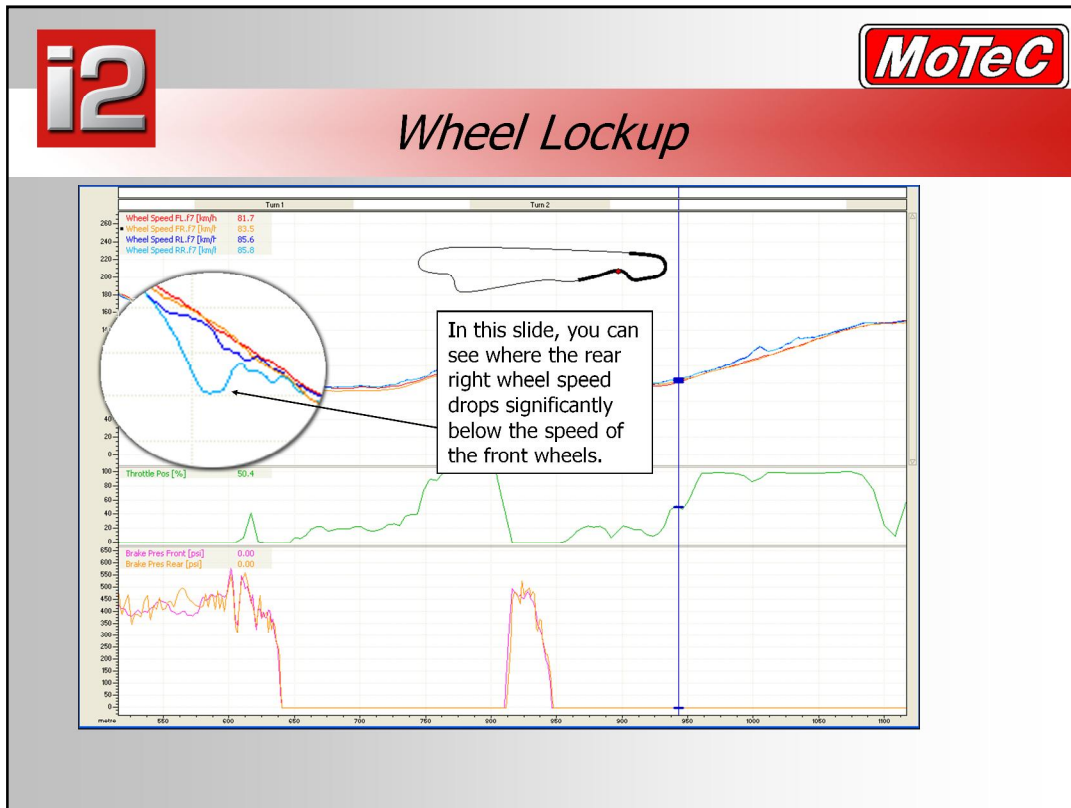
- Another very useful tool of the wheel speed comparison graph is to determine wheel lockup. To make this comparison, at least two front (or rear) wheel speed sensors are needed. The screenshot above shows all four wheel speeds together. It can be seen that the rear right wheel speed (light blue trace) has a very notable deviation from the other wheels.

- If a trace like this is encountered, it means that there is an imbalance in the car setup– whether it is caused by the driver, car setup or track conditions. It is worth looking at setup parameters other than just brake bias. Uneven corner weights, damper problems, brake pad compounds and temperatures and even oil on the track can cause such a lockup.

- As you would do every time you analyse data, be sure that what you think you have detected is really happening on the car. Use other sensors such at tyre temps, G sensors, and brake pressure sensors, and brake temp sensors to confirm your hypothesis. Especially here with an imbalance under brakes, you may be able to determine the cause of the issue, whether it be bias of line pressure or lack of braking friction to the front by looking at the Braking pressures versus G force and brake temperatures. You may have the same brake pressures front to rear, but have less retardation at one end to the other depending on calliper piston sizes, pad compounds, rotor types and brake temperatures.

1. **Place the cursor at 10.5 seconds and zoom in to look at the wheel lock up.**
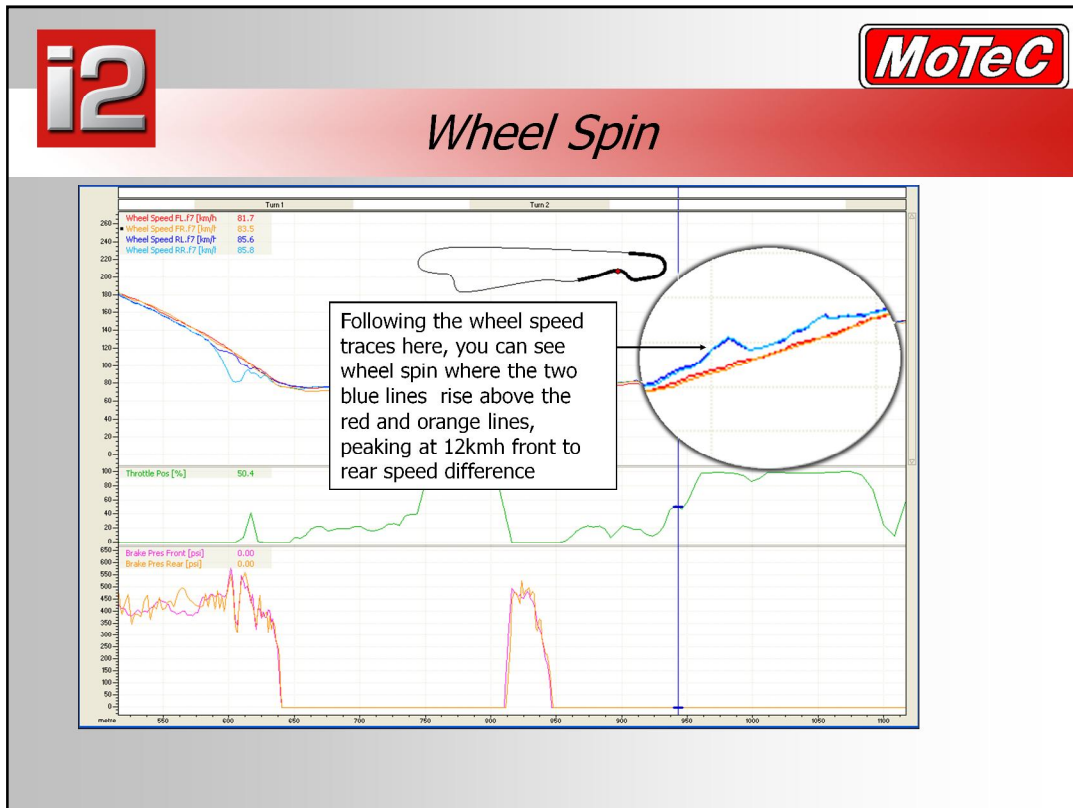
- Wheel spin is an important thing to be able to monitor in data logging. At the end of a session, the driver will reflect upon the performance of the vehicle, and determine what it is that is stopping the car from going any faster. With understeer and oversteer, common problems that a vehicle encounters at the limit, you want to determine what is causing the the vehicle to behave in this way. With oversteer, sometimes it is due to the suspension settings in the vehicle, whilst other times driving style is more to blame. Determining this is an important part of deciding how to go about tackling the problem.

- In the example above, you can see the blue lines(rear wheels) follow the red and orange lines(front wheels) until the zoomed section where you can see the blue lines go above the red ones. This is showing where the rear wheels are turning faster than the fronts.

- The causes of this could be wheel spin or wheel lock up, but by looking at where it is happening - going over the top of Mt Jane at Calder Park Raceway – very likely the rear wheel are unweighting. Does it happen every lap?

- Other sensors able to help confirm the scenario and the severity of the wheel spin include tyre temp sensors, G force sensors and throttle position sensors.

1. **Place the cursor at 27 seconds and zoom in to look at the area of wheel spin shown above**
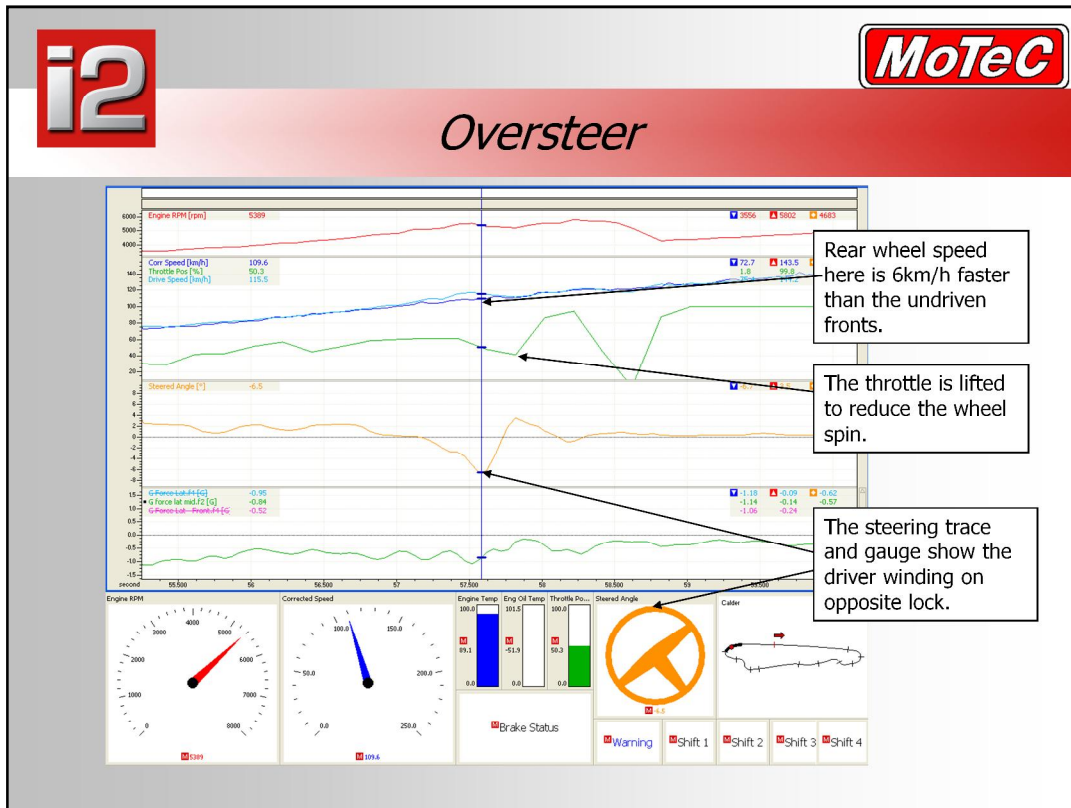
Oversteer

- Oversteer can also be recognized by a loss in lateral G force along with a steering correction by the driver and a reduction in throttle. The G-force trace is one in which we can see a balance problem with the car. The driver is unable to drive the car hard out of the corner for fear of spinning the car around, hence the decrease in lateral Gs at the exit of the corner.

- If we examine the steering trace we will be able to see how the driver is reacting as the car exits the corner. It is useful to be able to see this, as you can use it to measure the reaction time of the driver to the oversteer, and perhaps be able to better to quantify just how severe the oversteer is. This is an important measurement to make when trying to solve a handling issue, yes the car may still oversteer, but have we made an improvement or not.

- After observing the steering trace it is clear that the driver has quickly reacted to correct the situation by opposing the direction of the corner to prevent the car from swapping ends. A throttle lift often accompanies this trace, as it does in this case, but sometimes driver decides to power through the oversteer to compensate for the loss of cornering grip with pure forward acceleration.

1. **Select worksheet "2", "Gauges" from workbook "Samples"**
2. **Add a steering and throttle trace to the time distance graph**
3. **Zoom in to the data at 56 seconds into lap 2**
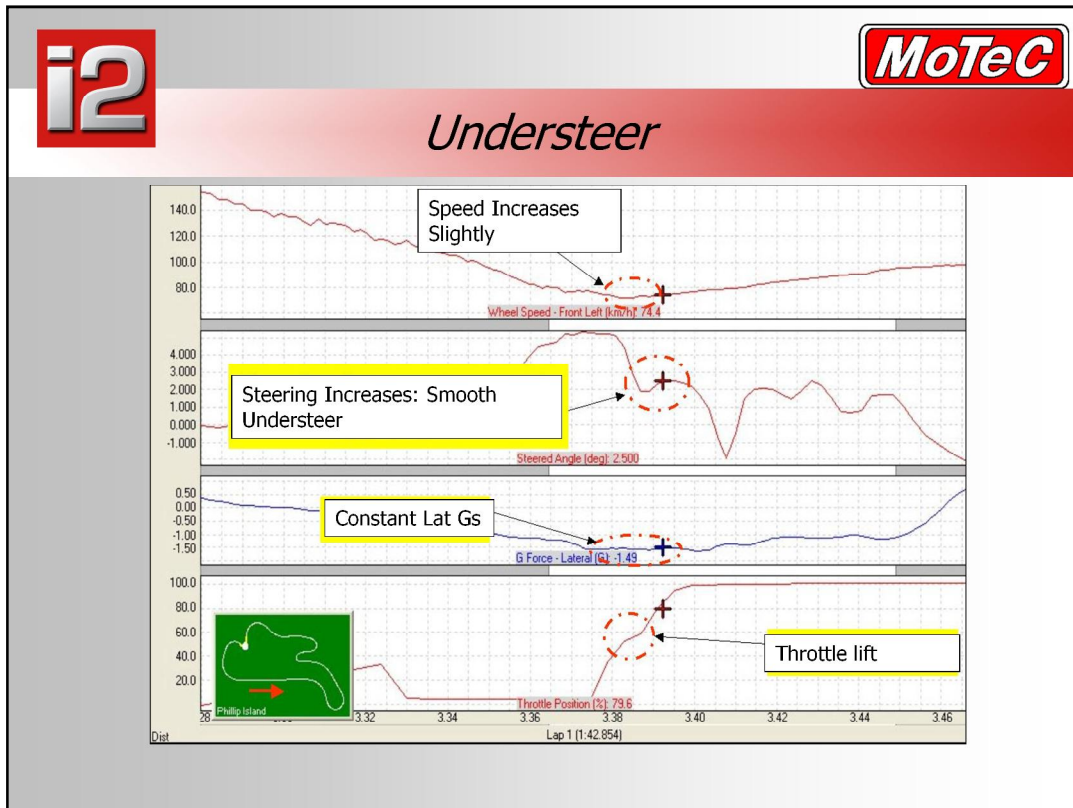
- In this example, the driver has started winding off the steering lock, and begun increasing throttle as the car comes out of the corner. Where the circles are, you can see that the driver has had to stop winding off lock, and had to wind it back on again. At the same time, it is noticeable that the driver has also had to stop feeding in any more throttle, and that the lateral G trace is constant. With an increase in steering lock and speed, you would normally expect to see an increase in lateral G force showing that the car is turning tighter. The flat G force trace at this point shows that the car is understeering, and the driver is being slowed by the understeer in this section of the track.

- It is useful to be able to determine this point, where and what sort of understeer is the car experiencing. Is it on turn in, mid corner, when you pick up the throttle, only when you get to the corner exit? By knowing this, you have a much better understanding on what part of the vehicle is most likely the main contributing factor in the understeer, and where to start changing things to fix the problem.

Tyre Temp Sensors
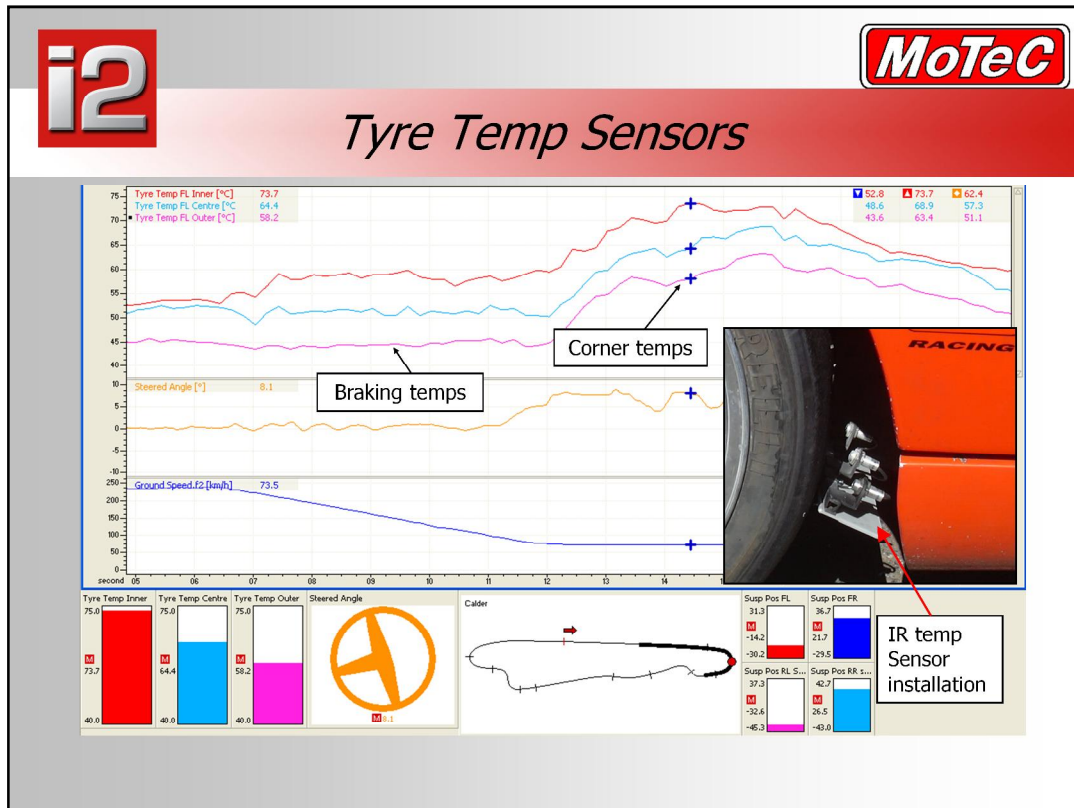
- Have you ever wondered how valuable the data is coming from measurements made with a tyre temperature probe? Do you want to make critical setup decisions from data that is strongly influenced by the length of the pit lane, your position on the pit lane, and the position of the pit entry on the track? What happens if the pit entry is just after a heavy lateral G corner? And what would be the temperature measured if this corner was oriented in another direction?

- Your tyre temperatures, by the time that you get to measure them, are heavily skewed by the last thing that happened to the car. If the pitlane entry is long, the tires would have cooled down considerably, and the temperatures may have equalised whilst driving down the lane. Perhaps due to static camber, you may see very high temperatures on the inside of a tyre in a straight line, but the same car may be very good under brakes and through cornering due to the caster and camber curves in the suspension design. So you may end up pulling off camber due to the high inner temperatures read by a pyrometer in pit lane, where the car may in fact be well set up for where it matters, under brakes and through the corners.

- Making setup adjustments based upon data coming from a tire temperature probe is unlikely to work because way too imprecise. The solution, as shown above, is to mount 3 infrared tire temp sensors by the wheel, continuously monitoring the evolution, turn after turn, of the tire temperature surface in the middle, the outer and the inner edge of the tire.

- Even if these tire temperature sensors are only taking the surface temperature of the rubber and not the core temperature like the probe, it can be easily demonstrated that the temperature of the tires measured in the pits are only giving a vague indication of what is really happening on the track.

- The measured pyrometer readings in pit lane from the car represented by the data above were:
  Inside 56   Centre 45   Outside 38

- These readings are in fact a reasonable representation of the temps actually seen in the car, but it isn't always the way pit lane and track dependent. Pyrometers also don't show you where it is exactly that temperature is coming from, down the straights (too much static camber) only in corners (not enough roll on camber or caster), only under brakes too much camber change under bump etc.

More Tyre Temp Sensors

On the right part of the graph, the temperatures are the one as seen in the pits when the car stops. On the left part of the graph, you get an idea of what is really happening on the track.

Example of tyre Temp installation
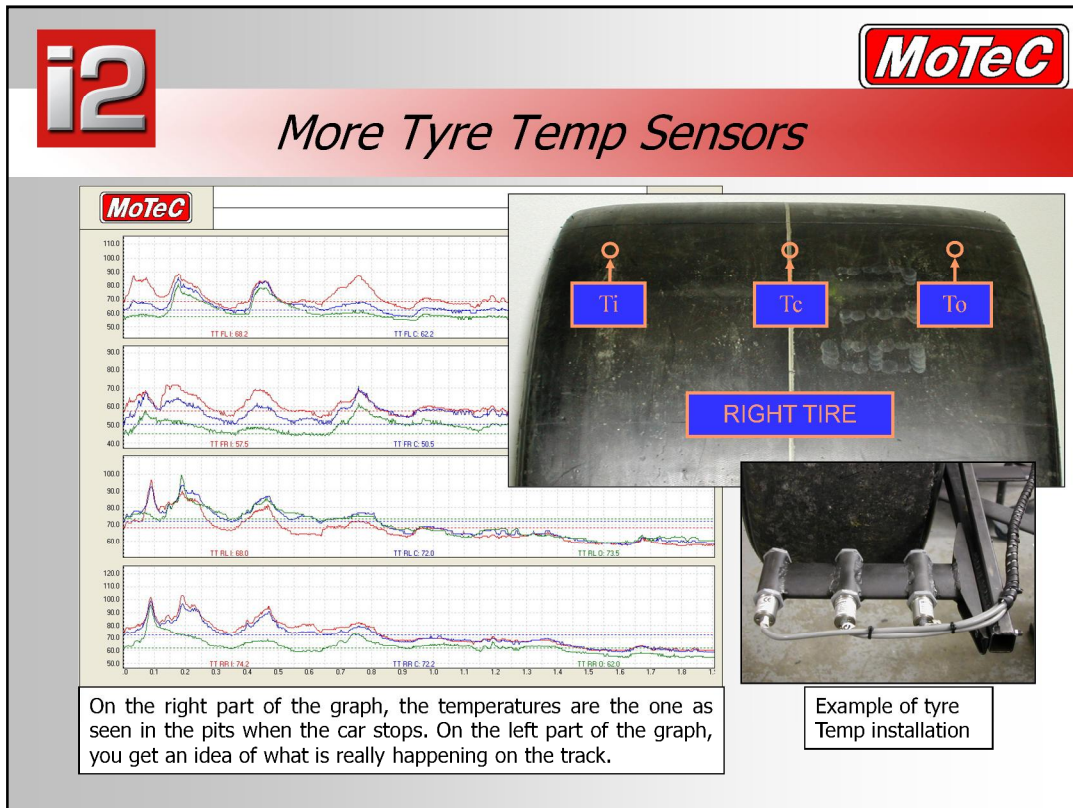
What Can I Learn From One or Three Tyre Temperature Sensors by wheel?

- Depending on the budget of the team, it is possible to install either one or three tire temperature sensors per tire. While it is possible to establish a clearer picture of how one tire is working with three sensors installed across the face of the tire, a large amount of information can be established by installing just one tire temperature sensor. The following information can be obtained if one tire temperature sensor is installed at the centre of each tire:
  – Load distribution
  – Brake distribution and balance
  – Wheel lock-up
  – Wheel lift
  – Traction loss/ wheel spin
  – Cornering temperatures
  – General dynamic operating temperature
  – Oversteer and understeer indications
- It is also possible to install three tire temperature sensors across the face of the tire to establish a clearer picture of how the tire is working, as shown above.
- The ability to understand temperature information across the face of a tire will allow the race engineer to tune the car more effectively, as well as monitoring the results of each change. As well as obtaining the information mentioned above for one tire temperature sensor, three tire temperature sensors could also acquire the following data:
  – Temperature distribution
  – Tyre inflation (over/under)
  – Camber adjustment (too much/little)
  – Toe (too much/little)
- Therefore, it is possible to conclude that one tire temperature sensor on each wheel will provide us with general information about the chassis and tire performance. Three temperature sensors will allow us to establish a greater understanding of how each tire on the car is performing, and permit individual changes to be made to each wheel allowing for maximum performance.

Tyre Temps Quick Guide

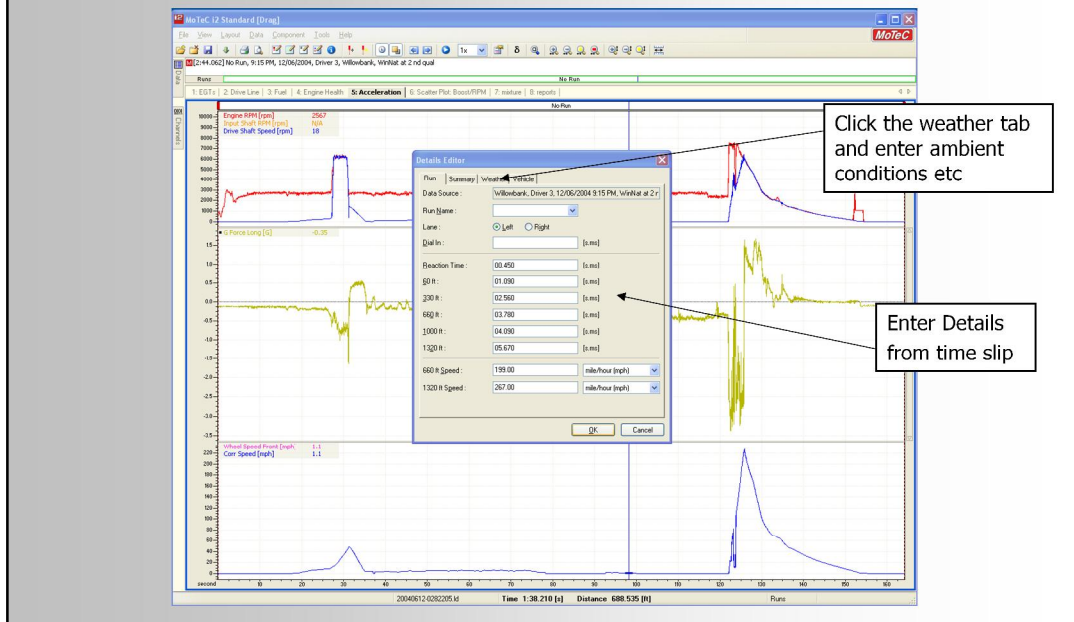|					
T_{INSIDE}	<	T_{CENTRE}	<	$T_{OUTSIDE}$	Not enough camber, or too much toe in.
T_{INSIDE}	<	T_{CENTRE}	>	$T_{OUTSIDE}$	Tire pressure too high.
T_{INSIDE}	<	T_{CENTRE}	=	$T_{OUTSIDE}$	Not enough camber, or tire pressure too high and too much toe in.
T_{INSIDE}	>	T_{CENTRE}	<	$T_{OUTSIDE}$	Tire pressure too low.
T_{INSIDE}	>	T_{CENTRE}	>	$T_{OUTSIDE}$	Too much camber, or too much toe out.
T_{INSIDE}	>	T_{CENTRE}	=	$T_{OUTSIDE}$	Too much camber, or tire pressure too low and too much toe out.
T_{INSIDE}	=	T_{CENTRE}	<	$T_{OUTSIDE}$	Not enough camber, or tire pressure too low and too much toe in.
T_{INSIDE}	=	T_{CENTRE}	>	$T_{OUTSIDE}$	Too much camber, or tire pressure too high and too much toe out.
T_{INSIDE}	=	T_{CENTRE}	=	$T_{OUTSIDE}$	OK

- The table above shows a quick reference guide, illustrating what adjustments might be made given the three tire temperatures measured at the points shown earlier. This table assumes that the optimal potential of the tire is achieved when the surface temperature at the inside, centre and outside are all equal.

Drags: Auto Run Insertion 1
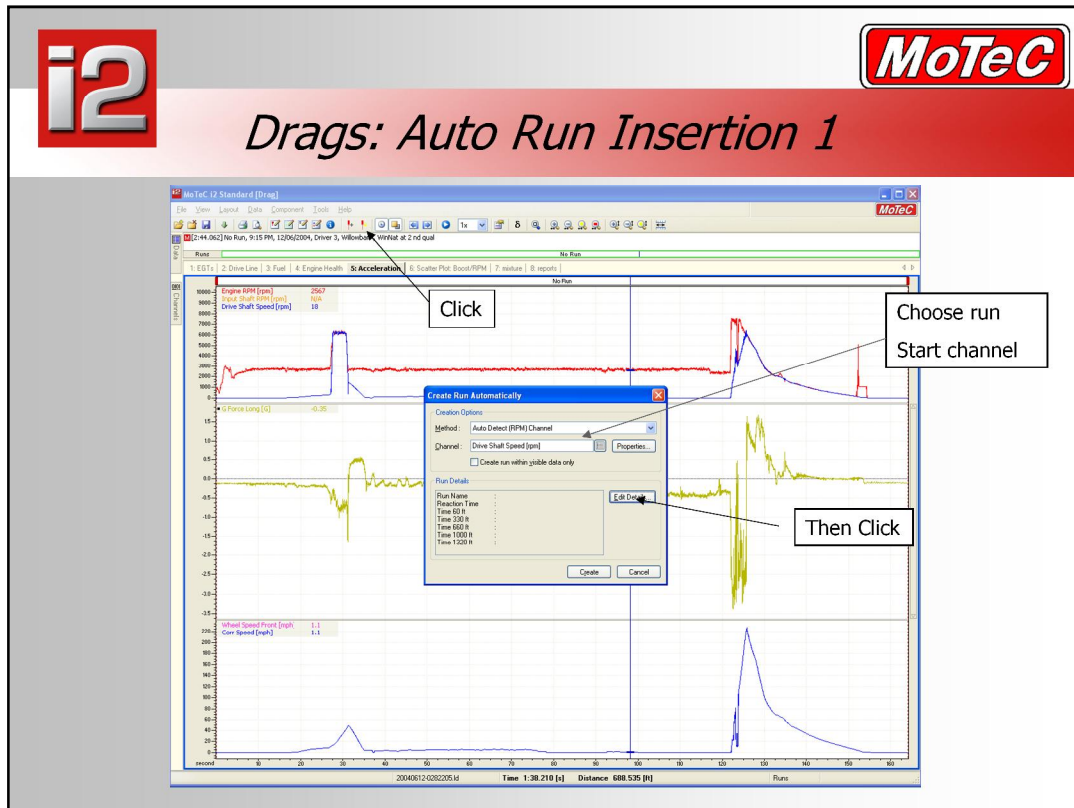
- i2 features an all new auto run insert function. With a few clicks of the mouse button the software can automatically insert the pass into the data with all relevant incremental times shown.

- Once set up, all your runs will start from exactly the same moment in each file, triggered from an event that occurs on the vehicle. This can be the first pulse from the drive shaft speed sensor or a signal from an on off switch such as a Wide Open Throttle switch. It is best to choose an event that indicates the actual forward movement of the vehicle. Testing indicates that is at about the data point showing Longitudinal G force greater than 0.2g

- The default method is to use the point where 'Drive Shaft Speed' starts to move. Though this can be changed to another channel.

- Once the start point of the run has been determined, we can enter information from the timeslip into i2, that will also be shown on the graph.

- Go into the "Tools" menu and choose the "Run Editor". From her choose "Edit Details", and enter the time slip information into the cells. At the completion of entering the time slip information press ok.

- Within here, you can also store other important details about the run, such as the weather at the time of the run, tyre temps, pressures, gearing etc so that later you can go back and see what contributed to a better or worse run that time.

- This will return you to the create run screen where all that remains is to click 'create' and the run will be highlighted in the data. To select the run press W for "whole run".
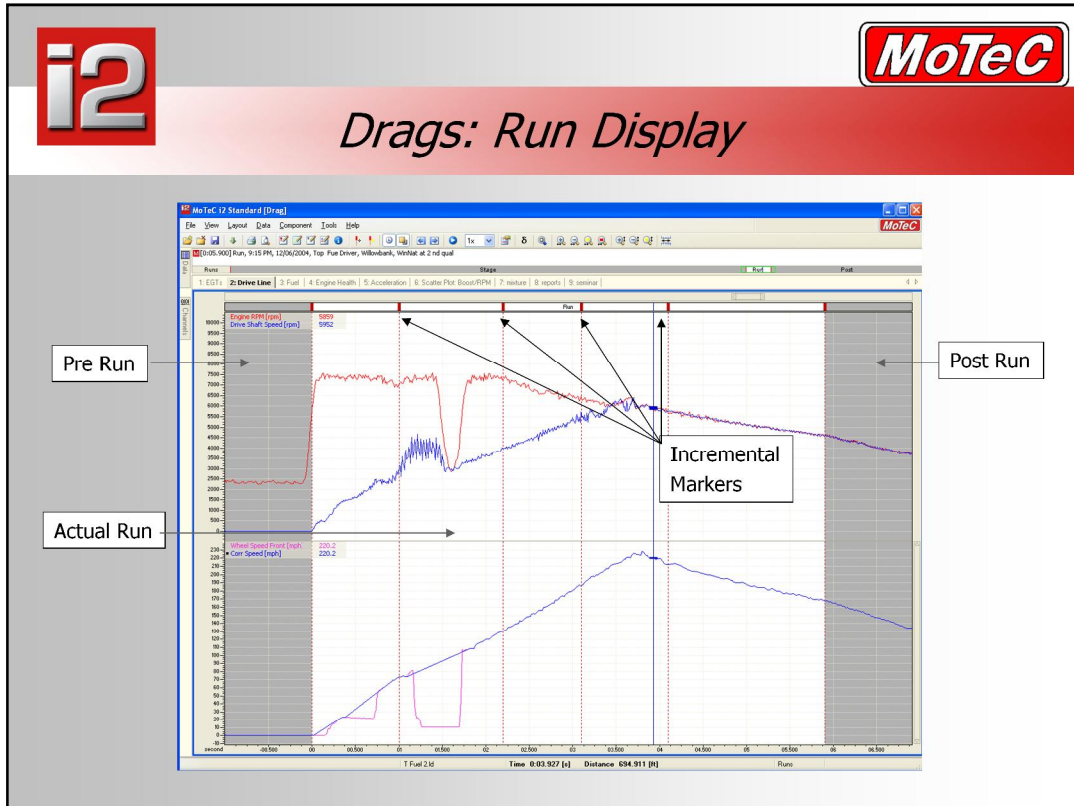
- Back in the data, the exact run is then displayed along with 1 second of data pre and post run with a grey background. Also displayed is the entered time sheet information. ie 60/330/1000 ft times. In the example above the blue corrected speed line on the bottom group shows the corrected speed and therefore distance travelled. This becomes particularly important for overlaying other files and reading Time and distance reports.
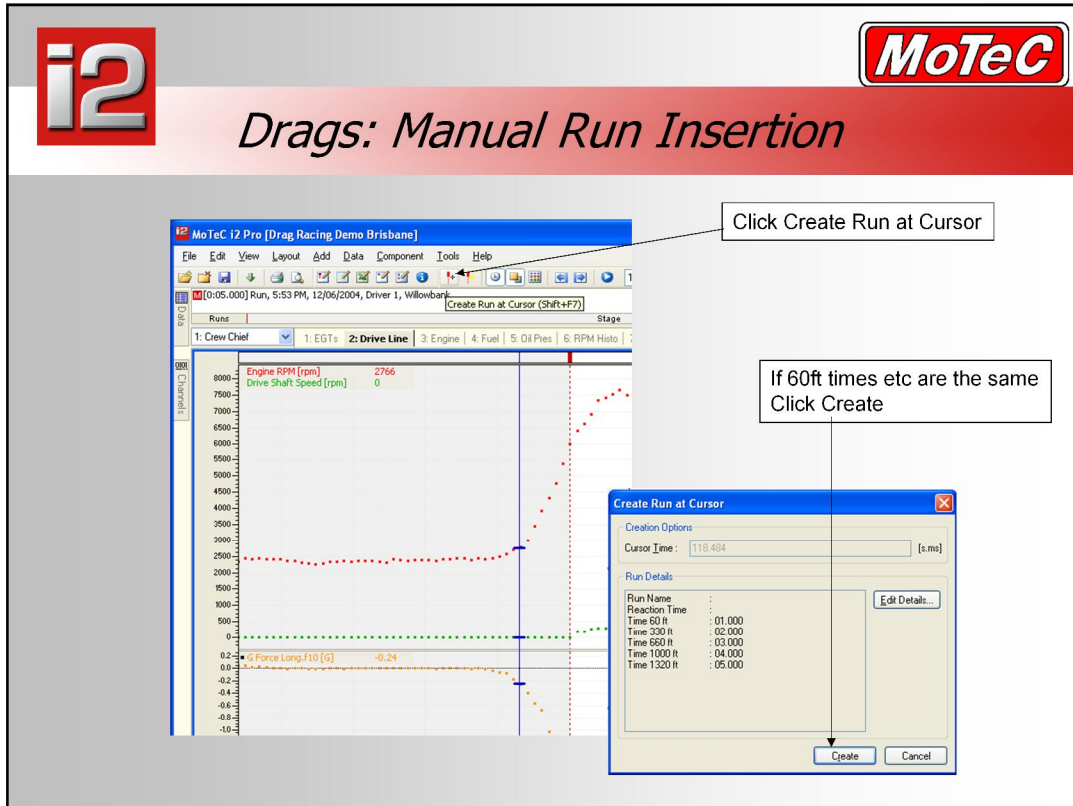
- If there is already a run on screen and its not in the right place you can easily shift it by using the Create Run at Cursor feature.

- In the above example the run has been previously auto created using the first drive shaft speed data point. Depending on the number of teeth on the drive shaft this point can be a long time after the car has actually starts to move.

- In the above picture we have changed the properties of the time/distance graph to show data points rather than lines. After some limited testing we have made a rough conclusion that most cars actually start to cross the beam somewhere around 0.25 G Longitudinal. The cursor (blue line) has been placed at this point and now by clicking the 'Create Run at Cursor' (Hot Key: Shift + F7) icon the run start point will be corrected. Assuming all incrementals are the same, click the create button and the run will shift to this point.
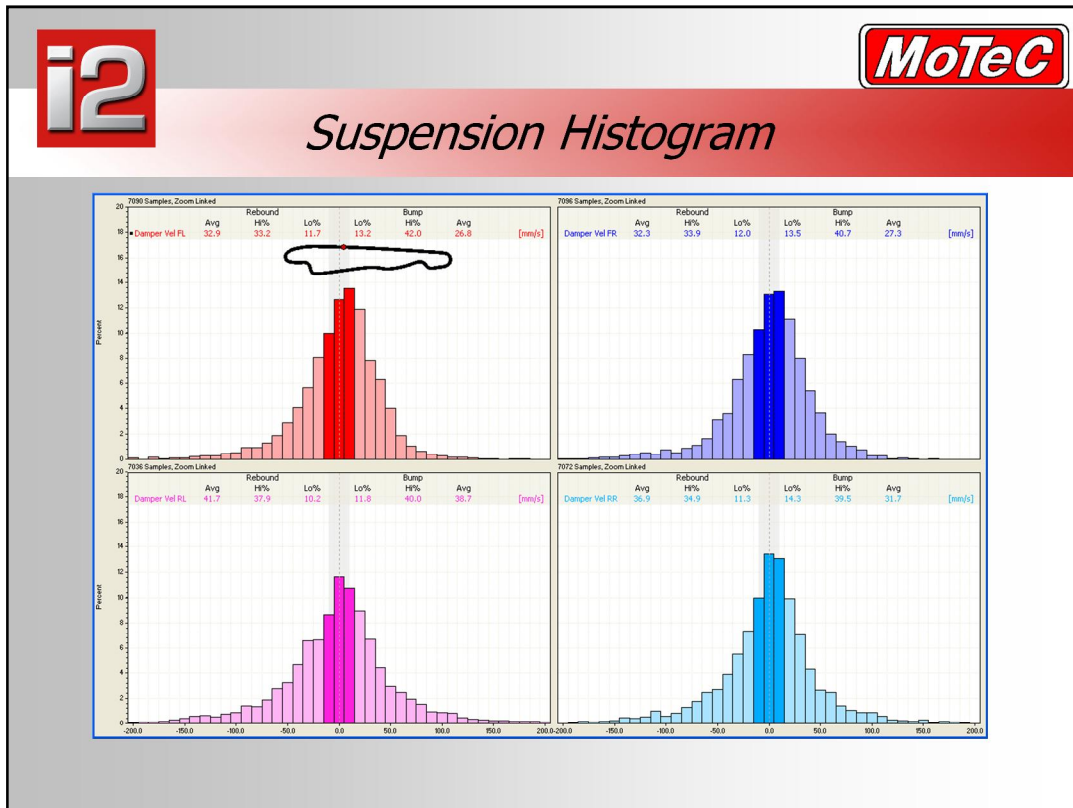
- The suspension histogram component displays histograms for a number of suspension velocity channels. The velocity channels are normally calculated from suspension or damper position channels. i2 includes built in velocity calculations. The calculations can be configured from the 'Velocity Calculation' page in the 'Suspension Histogram' properties. If needed these calculations can be turned off and the user can create thier own maths functions to generate the velocity channels.

Filter

- The velocity calculation includes filtering of the position channels to ensure good results when plotting the histogram. Without an appropriate amount of filtering the histograms may look "notchy". Note that too much filtering will reduce the high frequency content of the signal so too much filtering is also undesirable.

Style

- The histogram can be displayed as either a line graph or a bar graph. The channels can also be overlapped or displayed in a grid of panels. The bar style looks more like a conventional histogram however the line style is much more useful when comparing one channel to another or when the channels overlapped.

High Speed/low speed boundary

- A velocity can be nominated as the Hi Speed / Lo Speed boundary. This is normally set to match the high speed lo speed transition of the damper. This value is used in the various calculated info and is shown visually as band on the histogram.

Calculated Info

- The suspension histograms calculate the following data:
  – Rebound Avg: The average velocity of all values of rebound
  – Rebound Hi %:   Percentage of velocities falling in the rebound Hi speed area.
  – Rebound Lo %:   Percentage of velocities falling in the rebound Lo speed area.
  – Bump Avg: The average velocity of all values of bump
  – Bump Hi %:   Percentage of trelocities falling in the bump Hi speed area.
  – Bump Lo %:   Percentage of velocities falling in the bump Lo speed area.
- Note that "bump" velocities can be selected as either positive velocities or negative velocities (rebound will be the opposite).
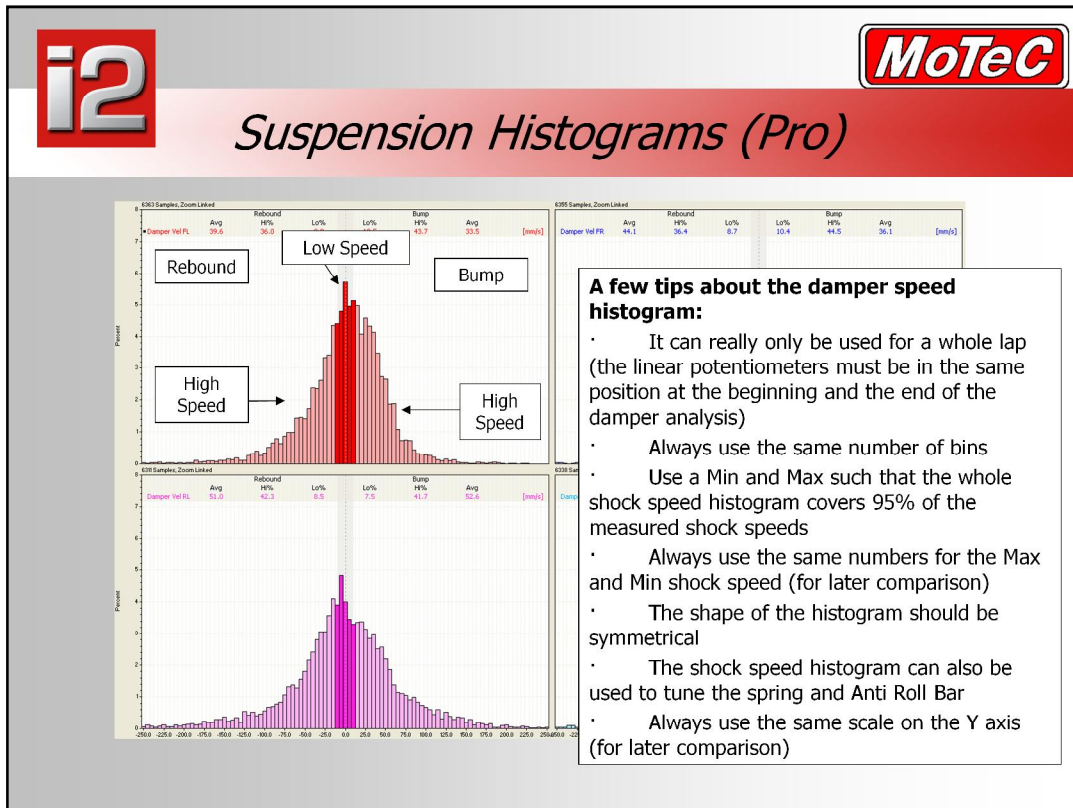
- Damper settings represent an interesting part of fine-tuning a racecar. Even if the basic principles are simple, without any tools it is almost impossible for the engineer to know if the dampers are really working at their best.
  - What's happening in bump?
  - What about in rebound?
  - Is the damping correct at high speed?
  - How can I check that the movement at low speed has been slowed down to improve my driver's "feel"?
  - How is any one damper working compared to the others?

- With four linear potentiometers on the car you can record where, when, and how each damper applies forces to the car.

- The damper speed histogram is a simple tool allowing us to check how the dampers are working. It refines the ratio between low and high speed, as well as bump and rebound, front and rear, left and right. It is also very useful for checking that your dampers have been set up correctly.

- The damper speed histogram shows the percentage of time (out of the lap time) that the shock is spending at certain speeds.

- The damper histogram is made up of four parts. Low speed bump, Low speed rebound, High speed bump and High speed rebound. A damper should always spend more of its time around the change of direction (0mm/s) than any other point on the histogram. It should spend progressively less and less as the graph goes from low speed to high speed. The change over point from low to high speed is vehicle and damper dependant but on a circuit racing vehicle often around 25mm per second. A balanced histogram should show a symmetrical curve. If you want a damper to spend more time in one point on the histogram, you need to stiffen up the damper in that region, to spend less time there, you need to soften the damper in that area.

Suspension Histograms2 (Pro)
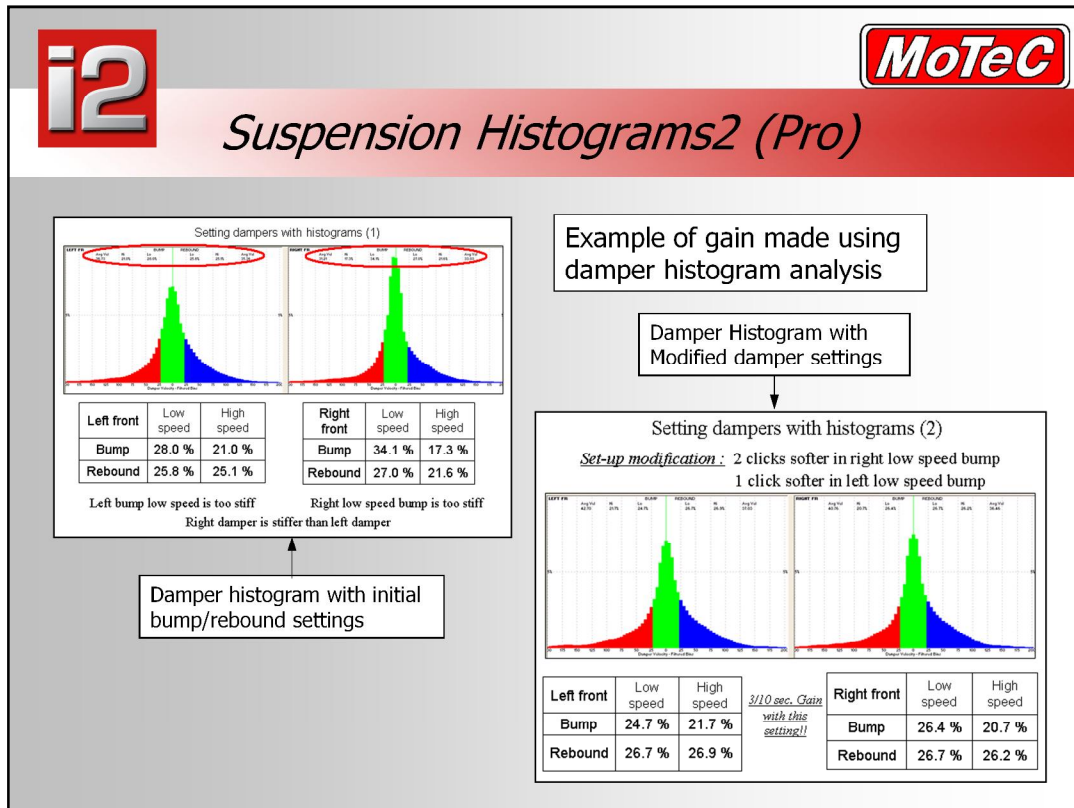
- By simple observation we can see that the 2 front dampers shown in the top left histogram do not seem evenly balanced. A good shock histogram should show a symmetrical curve. If we take the values displayed at the top of the histogram we can observe the percentage of time spent in low or high speed bump or rebound.

- When the histograms are compared to each other, we look at Low speed bump to low speed rebound, then High speed bump versus High speed rebound. We can deduce from the above histogram of the front left damper that the low speed bump setting is too stiff, as it is spending too much time there compared to the low speed rebound. So to fix this we would soften the left low speed bump settings, and in this example we softened it just one click.

- Looking at the front right damper, we can see that it is far more uneven it is spending 34% of time in low speed bump, with only 27% in low speed rebound. To even this out, we would soften the Right front low speed bump settings. That would increase the time spent in high speed bump, giving a far more even damper histogram distribution.

- In this actual example, the car gained 3/10ths of a second after making this change to the damper settings.
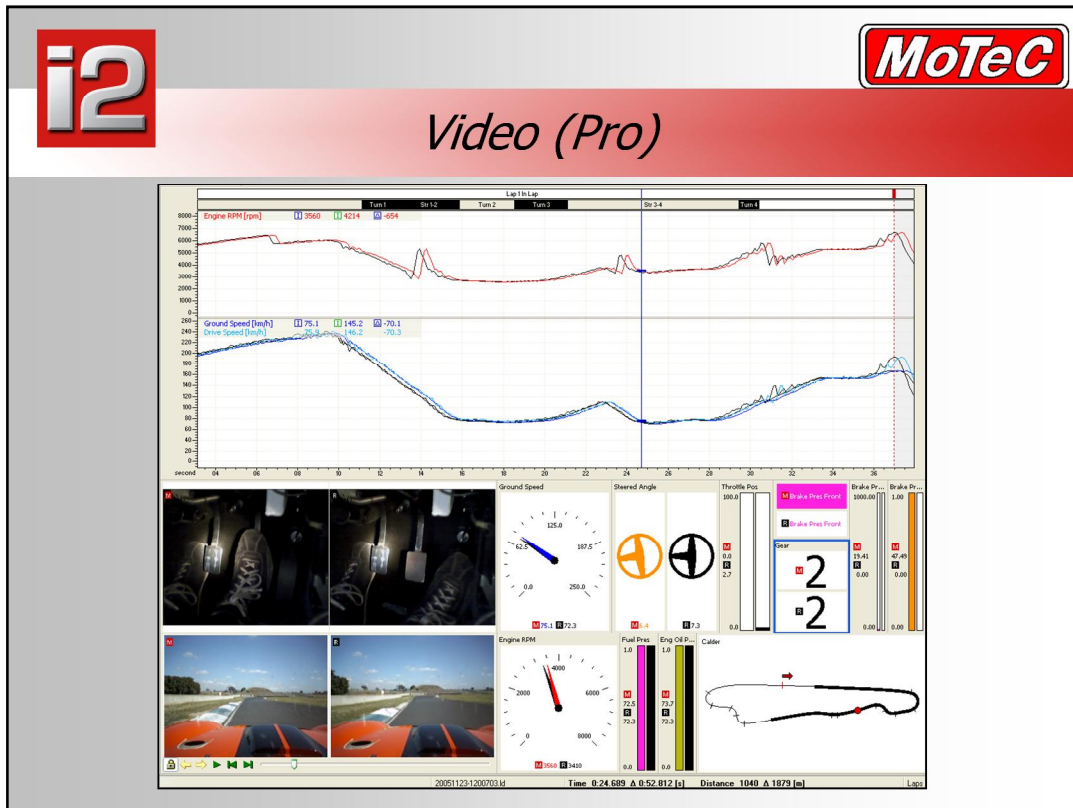
- i2 Pro includes MoTeC's integrated video function. This feature allows a video file to be linked to the logged data from a vehicle, and displayed along with the rest of your data within i2. You can, as in the example above, have one video on the driver, and another out of the car another on the suspension, and link them all together with the data. Note that utilising multiple videos is highly dependant on the quality of the PCs video card, files size, etc.

- Once the data and video is linked, when you overlay laps, you also overlay the video files, as shown above. You can then see how racing lines differ lap to lap, or how driver technique on the pedals is affecting lap times. This can become an invaluable training and analysis tool when used alongside MoTeC's data.

- The process of capturing video involves no MoTeC specific equipment, just the Pro Analysis upgrade on your logging device. You just log your outing, and video it, then transfer the video to your PC. From here you open i2 Pro, and add a video component to the worksheet. Using the properties of the video component, find and load your video file from the computer where it is stored. For this step, you need to link the data to the video, and this is done by finding a known event.

1. Fast forward the video to the start of the race, as an example.

2. Find the start of the race in the data.

3. Press the lock button to link these points together

- Now each time the data is loaded, the video is also loaded, and linked to the data where you set it. You need only set the link point once, and it stays linked from then onwards.
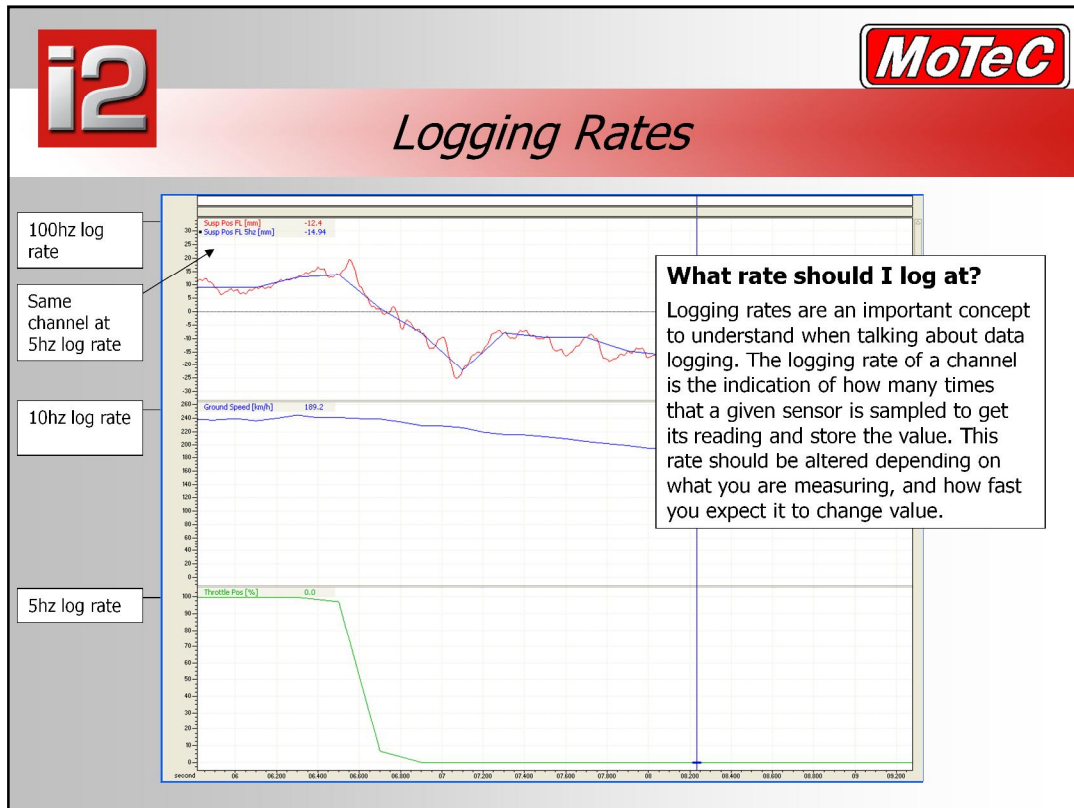
- Some examples of this are air an water temperatures, these will rarely change more than 1 degree per second, so logging this channel any faster than 1Hz will just duplicate channel values without really adding any extra accuracy to the data. A suspension potentiometer on the other other hand is moving very quickly, and as such needs to be logged fast enough so that you can read the intricate movements of the damper, and even differentiate that into a damper speed. Log rates for dampers should be a minimum of 100hz, normally about 250hz, and up to 1000hz in rough conditions. Obviously, the logging rates are a function of the amount of memory you have available and the type of sensors that you wish to log.
- The following list is a guide to suitable logging rates:
  - Oil and water temperatures   1 Hz
  - Oil and fuel pressure, Gear   2 Hz
  - Voltage   5 Hz
  - Brake pressure, temperature   10 Hz
  - Steering, Wheel Speed   10 to 50 Hz
  - Tire Temperatures and pressures   10 to 200 Hz
  - Accelerometers and Yaw sensors   50 to 500 Hz
  - Shocks and strain gauges   100 to 1000 Hz
  - Slip Angle Sensors   200 to 1000 Hz
  - Throttle position   10 to 50 Hz
  - Linear potentiometer   50 to 200 Hz
- It should be noted that when performing math functions on channels logged at different rates there is some inaccuracy, as the samples point do not match at every point. If we want accurate math functions we should log the channels at the same rate, resulting in an answer with greater accuracy than if the channels were logged at different sampling rates. For example:
  - Signal 1 (logged at 5Hz) * signal 2 (logged at 50Hz) = result (as if it was logged at 5Hz)
  - Signal 1 (logged at 10Hz) * signal 2 (logged at 10Hz) = result (as if it was logged at 10Hz)
- A quick guide to sample rates.
  Sensors should be sampled at twice the sensors update rate for the best accuracy for that sensor if its update rate is known.
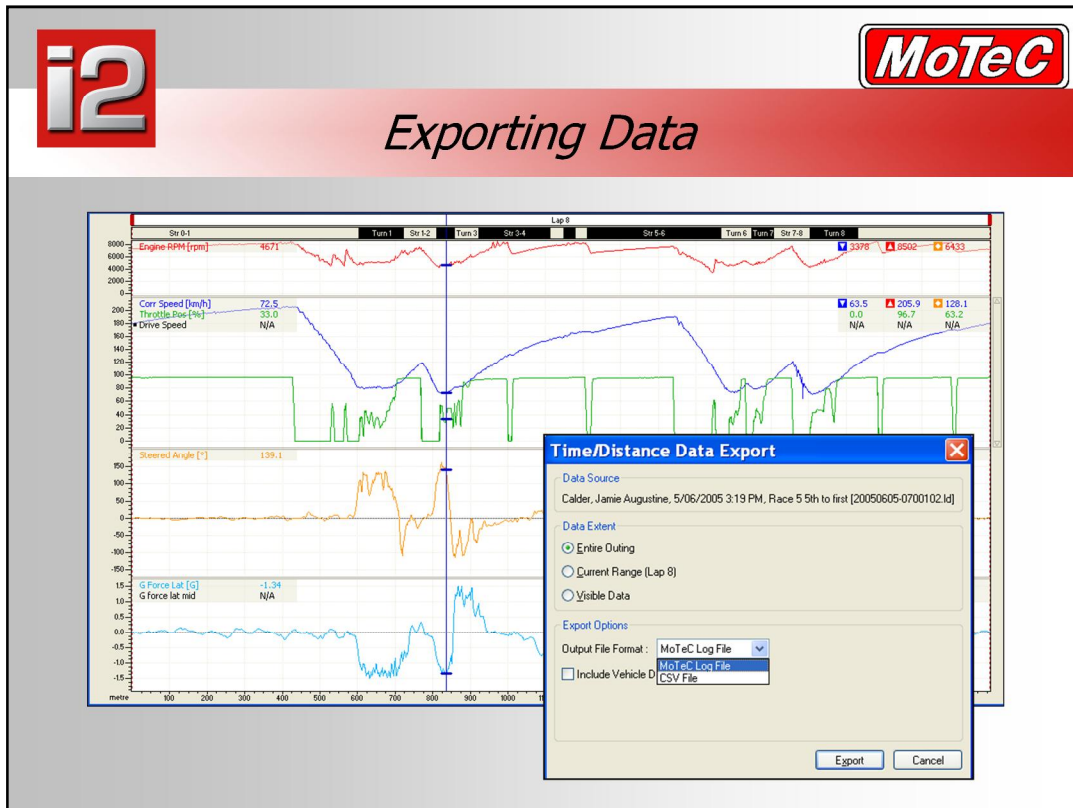
- If you want to process your data using methods not available in i2, or perhaps you want to send someone part, but not all of your data, then there is an export facility in i2. Export allows you to save your data in one of three formats, either CSV (Comma delimited text file) suitable for Microsoft Excel or other non MoTeC applications, the Matlab data format (i2 Pro), or the MoTeC log file format, which will let you open the new file in i2 again.

- The **File menu** has an item called "**Export**". This will always export all of the channels in your file to another log file or a CSV file. Often people wish to export a subset of data, this is done by creating a graph with just those channels that you wish to export shown. Then **right-click on the graph** and select "**Export Data**", only those channels on this graph will be exported.

- Both functions allow you to select the timeframe over which to export data: Entire outing (the whole log file) Current Range (eg: a lap) Visible Data - just the time/distance range shown on screen, eg: after zooming in.
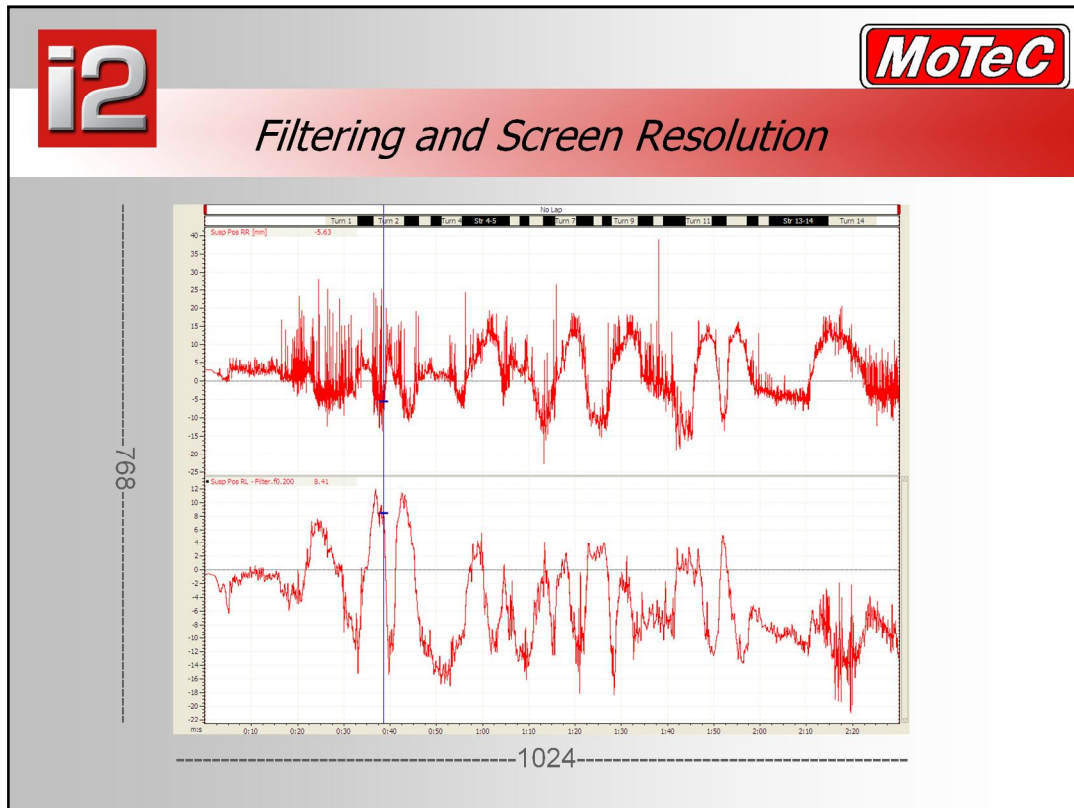
- Firstly, it is important to observe the raw data because this could already highlight some car setup problems, or sensor installation/wiring problems.

- Moreover, you may see differences between vibrations in compression and in rebound. Raw data from shocks or strain gauges could be difficult to understand in terms of noticeable car attitude change, especially without zooming in. A filtered signal allows overall trends to be seen without any zoom needed. However, it is important to have a look at them first without applying any filter to be sure that you do not miss a part of the behaviour.

- In the same way, it's important to also consider that the size of your screen also acts like a filter.

- For example, say that your computer resolution is 1024 x 768 and you are looking at data logged at 20Hz. At the best you will see only 1024 / 20 = 51.2 seconds of the data without any filtering. So if you look at an entire lap that is longer than this you are necessarily "filtering" – not all of the data points will fit onto the screen. If you want to see the each point, you need to zoom onto a segment equal to or smaller than 51.2 seconds.

- Changing the display to show 'Points' rather than lines will quickly tell you if you are seeing all of the data or not.

| Precision of the measurement (in meters), in function of the logging rate, for different speeds.								
	logging rate (Hz)							
Speed (km/h)	1	2	5	10	20	50	100	200
20	5.56	2.78	1.11	0.56	0.28	0.11	0.06	0.03
40	11.11	5.56	2.22	1.11	0.56	0.22	0.11	0.06
60	16.67	8.33	3.33	1.67	0.83	0.33	0.17	0.08
80	22.22	11.11	4.44	2.22	1.11	0.44	0.22	0.11
100	27.78	13.89	5.56	2.78	1.39	0.56	0.28	0.14
120	33.33	16.67	6.67	3.33	1.67	0.67	0.33	0.17
140	38.89	19.44	7.78	3.89	1.94	0.78	0.39	0.19
160	44.44	22.22	8.89	4.44	2.22	0.89	0.44	0.22
180	50.00	25.00	10.00	5.00	2.50	1.00	0.50	0.25
200	55.56	27.78	11.11	5.56	2.78	1.11	0.56	0.28
220	61.11	30.56	12.22	6.11	3.06	1.22	0.61	0.31
240	66.67	33.33	13.33	6.67	3.33	1.33	0.67	0.33
260	72.22	36.11	14.44	7.22	3.61	1.44	0.72	0.36
280	77.78	38.89	15.56	7.78	3.89	1.56	0.78	0.39
300	83.33	41.67	16.67	8.33	4.17	1.67	0.83	0.42

- During the study of the various curves, there are two points that are important to remember. Firstly, it is important to understand the influence of the logging rate on the measurement precision. Then, it is useful to have an idea of the consequences of the driver's mistakes at high speed.

- This table shows the distance in meters between two measurements for different combinations of logging rates and vehicle speed. As an example, let's consider a car at 200km/h with a Lateral accelerometer logged at 20Hz:

- Distance travelled per sample at 200km/h is:
200x1000/3600x20 = 2.78m

- In an average data logging configuration gear changes are recorded at 10 Hz. At 200 km/h, if two drivers are changing gear at exactly the same time, on the data acquisition system it can appear with a difference of up to 5.5 m.

Distance driven (in meter) due to a driver mistake							
	mistake (sec)						
Speed (km/h)	0.05	0.08	0.1	0.2	0.3	0.4	0.5
180	2.50	4.00	5.00	10.00	15.00	20.00	25.00
200	2.78	4.44	5.56	11.11	16.67	22.22	27.78
220	3.06	4.89	6.11	12.22	18.33	24.44	30.56
240	3.33	5.33	6.67	13.33	20.00	26.67	33.33
260	3.61	5.78	7.22	14.44	21.67	28.89	36.11
280	3.89	6.22	7.78	15.56	23.33	31.11	38.89
300	4.17	6.67	8.33	16.67	25.00	33.33	41.67

- On the following table, the consequences of the driver's response times at high speeds are illustrated for several combinations of speed and 'mistake times'.

- As an example, if the driver misses the braking point at 220 km/h, by 0.1 sec, there is a delay of more than 6 meters.

- So it is important to understand that when you add the difference due to the low logging rate, to the driver's mistake (small mistake in absolute time, but with huge consequences at high speed), you obtain a difference of 20 meters between two drivers who think that they are braking exactly at the same time because their lap time is roughly the same.
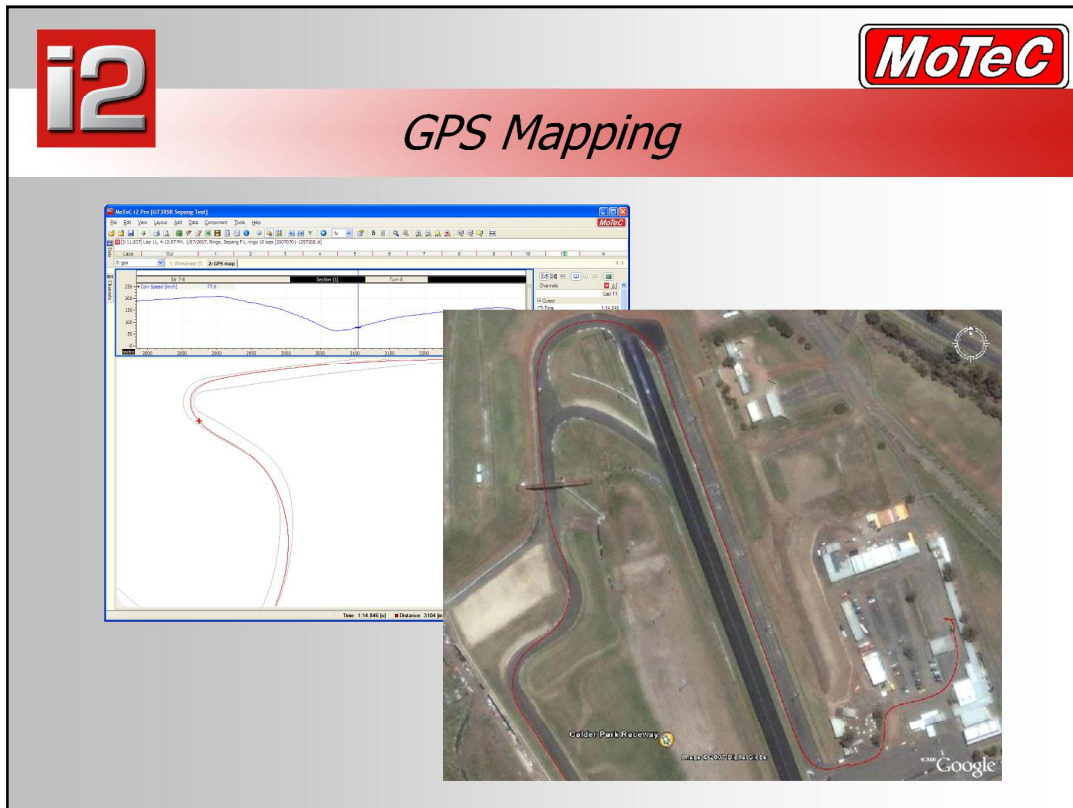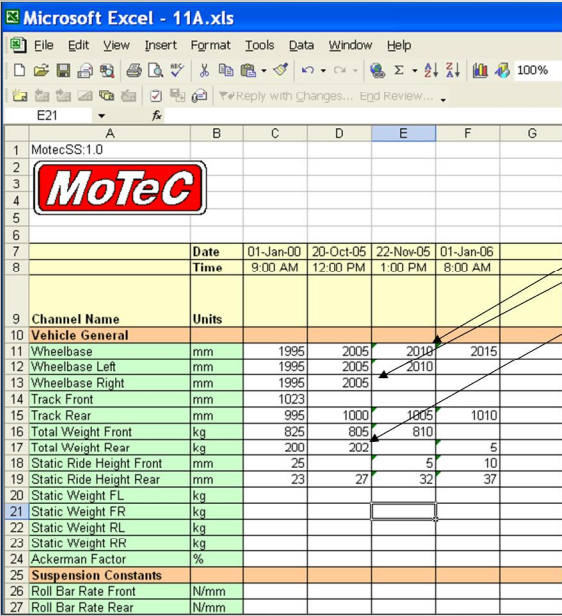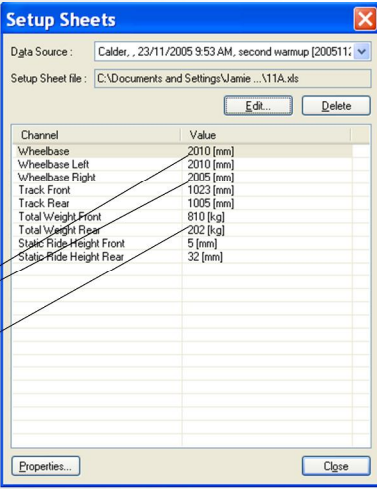
- Until fairly recently it has been quite common to use GPS for Ground Speed and Compass Heading in vehicles which were not able to use more conventional speed sensors. One drawback has been that most GPS units available would only transmit data at the relatively slow rate of 1 Hz, meaning that the position data of Latitude and Longitude, was not very useful – and there was also a large lag in the speed trace. With better GPS units now available offering much higher data transmission rates, (5 Hz, 10 Hz and 20 Hz) it is now possible to use the position data for much more interesting functions in *i2*.

- Track maps in *i2* can now be created purely from the GPS data with no other sensors needed. See example above. i2 will allow also you to use an export function to place your driver's line into Google Earth. The function is under the 'File' menu and creates a kml file that is compatible with Google Earth from the position data that is currently visible on the graph. Note the red trace in the image above right.

- Setup Sheets are a method by which users are able to track changes to their car, along with making these changes available to be used as a constants within i2 for Maths calculations. It can be thought of as a flexible extension to the details editor area per car and session. The sheet is built and pre formatted by i2, and there is one created per car id. In your log file details, you specify an ID for your vehicle. This id must be unique to that vehicle, as this is used for the name of the setup sheet. To start a setup sheet, click on the "Create" button, which then becomes the "Edit" button. This creates the setup sheet named {Vehicleid}.xls, and opens it for editing.

- The sheet, once created, is relatively free format, you can change or add any channel name, it just needs to start in column A. You can choose from any of the available channel units that i2 recognises for your channel, if there are no suitable units, leave it blank and it will come across as unitless. Next, add the time/date stamp for your data. To decide which constant is suitable for the currently selected log file, i2 looks at the download time of the log file, and finds the last column that the log file was created after. If there is a value in that row, it takes that value. If it is blank, then it goes back one column at a time until it finds a value, which it uses as the value for that channel. So you can see in the above example, that the file date of 23/11/2005 would make it use the column 'E'. Here it chooses the 'Wheelbase' of 2010, 'Wheelbase Left' of 2010, but has to go back to column 'D' to find a value for 'Wheelbase Right'[, at 2005mm.

- There are a few more things to note about setup sheets.
    - If two blank cells are seen in a row in column A(after row 10), it is deemed that there are no more channels to process.
    - There is one sheet per vehicle ID, per project, so be sure to use the same project each time for your car.
    - You can use formulas to create values in the cells, only the final result is used within i2.
    - If you have further calculations to do for your formula, do them on another sheet, as it only looks at the first sheet of the workbook when looking for the setup sheet.

1. **To view the setup sheet, click on the "Tools" menu, then "Setup Sheets", or Control-T**
2. **If there is a button called create, click that to create a sheet, else used Edit if it already exists**
3. **Add some numbers into cells C11, C12, C13 and C14**
4. **Save and close the spreadsheet.**

- The above are new features added in release 1.02.019 (release date July 2007)
- New Maths Functions (see maths help for details)
  - time_valid(condition, duration)
  - edge_delay(channel, time, edge_type)
  - range_is(range)
  - range_change(range)
  - flip_flop(set_condition, reset_condition)
  - stat_start(channel, condition, reset)
  - stat_end(channel, condition, reset)
  - stat_min(channel, condition, reset)
  - stat_max(channel, condition, reset)
  - stat_std_dev(channel, condition, reset)
  - stat_mean(channel, condition, reset) – added condition and reset
  - Integrate(channel, condition, reset) – added condition and reset

To Finish with

- In the extremely unlikely event that you have an i2 crash, we would like to hear from you with the information so that we can continue to improve the product.
- If you need assistance, feel free to drop us a line here at support@motec.com.au
- If you have suggestions on possible improvements or feature requests we can look into it for you.
- Send i2 questions and feature requests to i2@motec.com.au

- Questions?