OXFORD BROOKES UNIVERSITY

School of Technology

Learning while Earning

An Innovative Approach to Motorsport Industry Employee Education

School of Technology

Vehicle Dynamics Expo, Stuttgart Messe, June 24th 2010

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VEHICLE DYNAMICS INTERNATIONAL HIGHLY COMMENDED Development Tool of the Year 2009

Partnerships – co-operation producing and delivering education to a highly competitive sector

- Brief background to setting up the Motorsport Knowledge Exchange project;
- Co-operation between specialists @ Oxford Brookes University (motorsport) and the Open University (distance learning) and industry itself in producing CPD short courses;
- Overview of courses in Chassis Dynamics + a look at Data Acquisition, and Business – all for motorsport;
- Summary of project experience and future aims.

Recent Parliamentary Report (March 2010)

House of Commons

Business, Innovation and Skills Committee

Full speed ahead: maintaining UK excellence in motorsport and aerospace

Report of session 2009 – 10, pub. March 2010

UK Motorsport In – our 'Motorsport Valley'

Approx. 40,000 jobs (25,000 Engineers); 4500 companies, 90% SMEs

€4.8 bn. p.a. sales (60% exports)

Spends *circa* £1.8 billion *p.a.* (30% of sales revenue) on R&D (UK average: 2% spend)

Eight Formula 1 teams – six within 50 mile radius of Oxford Brookes and Open Universities

World-class automotive/motorsport consultancies *e.g.* MIRA, Prodrive, Xtrac, Menard *etc*.

Fastest-innovating industry in the world – typically, only 10% of the car on the grid at the beginning of the season remains at the end (and you're abilities are tested in front of a global audience (1bn. people over a race season) on a fortnightly basis

Oxford Brookes 13 years in motorsport education

- €2.5m regional Government funds – part-funding €12m 6000 sq.m. Motorsport Engineering Centre (opened in 2007);
- €1.9m+ motorsport industry in-kind pledges to Motorsport Engineering Centre project;
- €1.2m Motorsport Knowledge Exchange 5-year project;
- €240k Motorsport CPD project (Continuous Professional Development) to develop online short courses

Brookes in-house motorsport/auto students

- Student employability – 17% direct into F1; 43% other motorsport; 10% post-grad motorsports; 30% other (incl. automotive)

Destinations and roles

- **Where they go**
  - RenaultF1, WilliamsF1, SpykerF1, Torro Rosso, MidlandF1, HondaF1, Red Bull F1, BMW F1, Super Aguri F1, Jordan GP, Arrows F1, TWR F1, Lotus, Prodrive, Xtrac, BMW Mini, BMW Motorsport, Ray Mallock, Jaguar, AP Racing, Nissan Motorsport, Delphi, MoTeC, Pilbeam, TWR Race Engines, Ford, Porsche Motorsport, Bridgestone Motorsport, McLaren Performance Cars, MG Rover, Eilbach Dampers, Optimum G, Rouse Technology, Slark Race Engines, Millbrook Proving Ground, Caterham, PYW, Ascari, Delphi, Pilbeam, Honda Road Cars, Integral Powertrain, Plenum Motorsport, Zeus Motorsport
- **What they do**
  - Race Engineer, Aerodynamicist, Design Engineer, Rally Engineer, Data Engineer, Test Engineer, Project Engineer, Graduate Engineer, Sales Manager (three of the current F1 Race Engineers – the youngest on the grid – are former Oxford Brookes students)

The Brookes Motorsport Engineering Centre

The ‘Race Shop’

The Open University – humble start

Began in 1970

'Open' – for most courses: no previous qualifications needed

'Distance' – **supported** open learning

The Open University - now

Over 150,000 undergraduate

Over 30,000 postgraduate

Nearly all part time

About 70% in full time employment

25,000 students outside UK

The Motorsport CPD programme

- Market-driven/industry-focused - born out of prime findings from UK Government's DTI Motorsport Competitiveness Panel:

  '(We) *recommend that a series of supplementary post-graduate courses be funded to accommodate the needs of individuals wanting to become involved in motorsport.'*

  'Surveys found a need for short, effective courses, delivered flexibly.'

- Target market: employee upskilling – but whilst still working

- No limits to student numbers, location, study timeframe (within reason)

How do the distance learning courses work?

- Employ '*roll-on-roll-off*' delivery model - 24/7, 365 days/year enrolment structure
- Delivered 'at a distance' (but with optional, boot-camp-style intensive residential practical sessions);
- Students study at a time, place and pace which suits them – at work, at home, in airports *etc.;*
- Allocated tutor support – students learn by doing many structured exercises;
- Course 'packs' include printed workbooks, processing software (*e.g.* MATLAB, ADAMS, ChassisSIM), supporting magazine articles and learned papers, DVD, on-line activities;
- Course progress (generally) achieved by completing sequential online exercises (requires 100% pass at each assignment stage);
- End-of-course assignment in form of project dissertation (or exam) , based on current industry real-life issues.

Education **(not simply training)**

- Philosophy behind courses is *understanding* – to make best safe use of all tools available to improve competitive advantage

  'You don't do the calculations until you understand what the problem is'.

  Keith Duckworth, co-founder Cosworth, quoted in Motor Sport magazine, June 2000

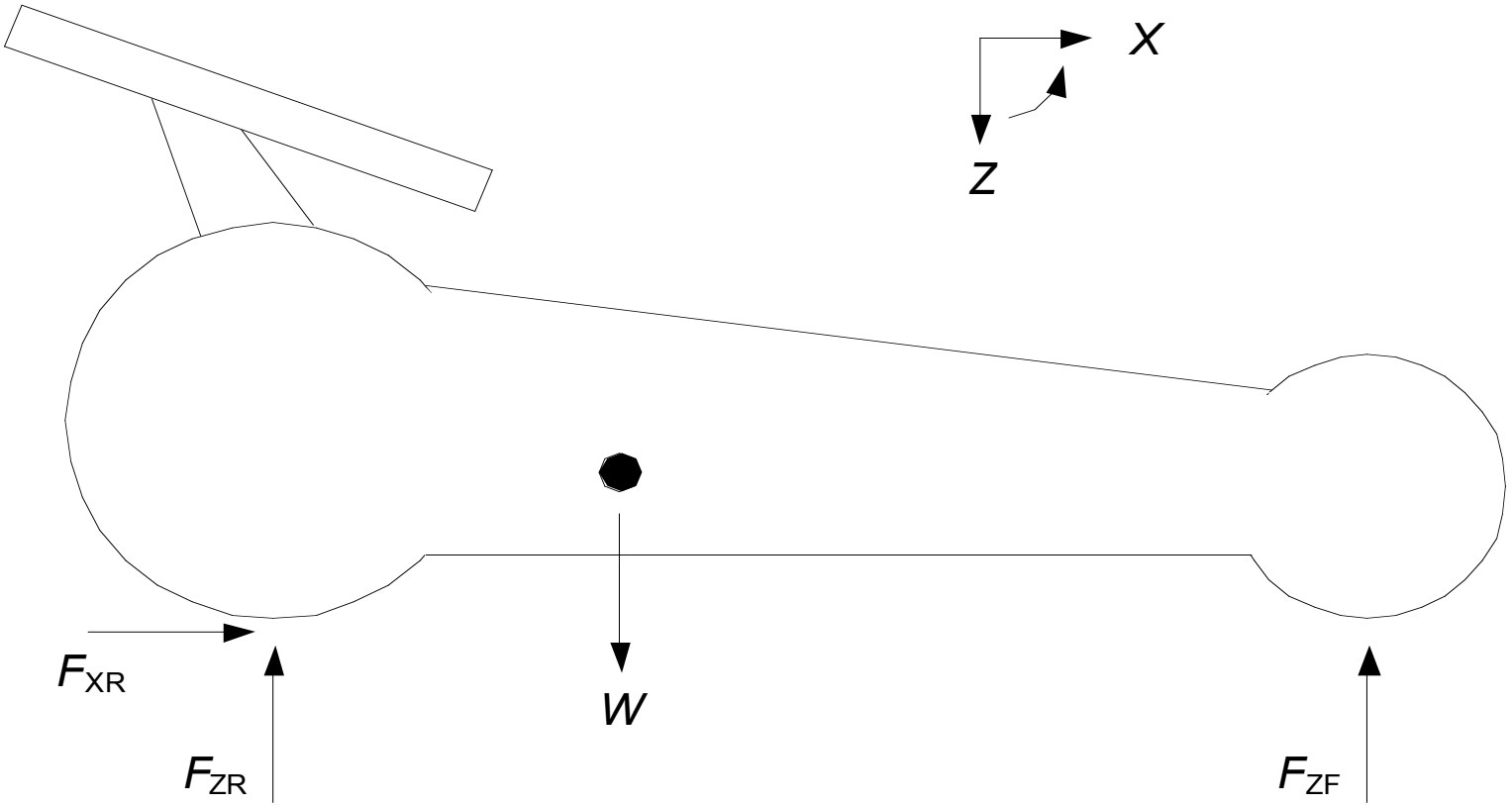
Motorsport Chassis Dynamics

Post graduate course:

- Developed with key input from senior staff at the RenaultF1 team, Williams F1, Dunlop Motorsport, and ChassisSiM
- Six Course Workbooks, with comprehensive and well-researched '*Tyres'* module, (included specifically at F1's behest), as well as a DVD/ wide selection of contemporary industry Case Studies
- Extensive ADAMs and ChassisSim simulation exercises
- Optional practical sessions using fully-instrumented Formula Renault race car, on-track and Multimatic 4-post rig
- Various course options available to appeal to different student aspirations/ industry markets/ study timeframes/budgets

Dragster on ‘full noise’

Free body diagram equivalent



Free body diagram equivalent

Maximum safe acceleration;

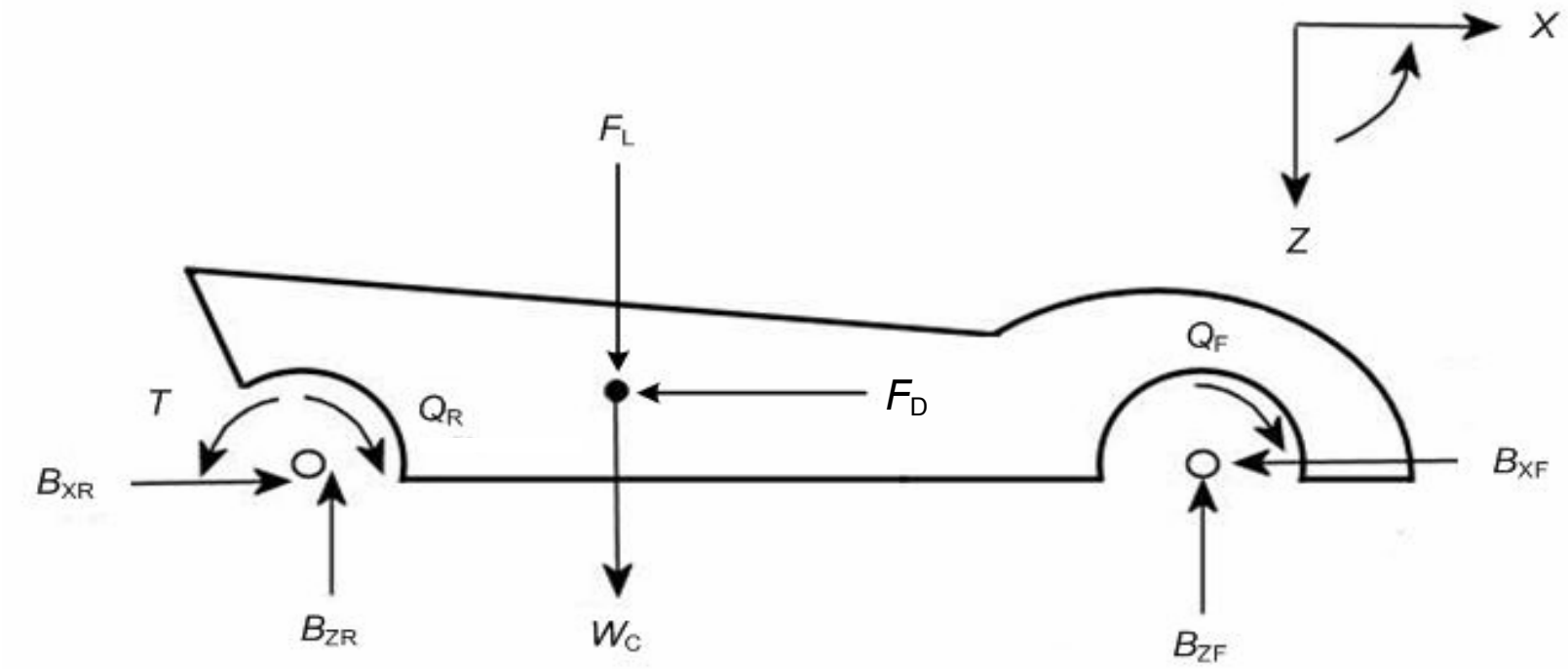
Centre of mass position to minimise wheelspin;
(Too far back, too far forward?)

Vary height of centre of mass;

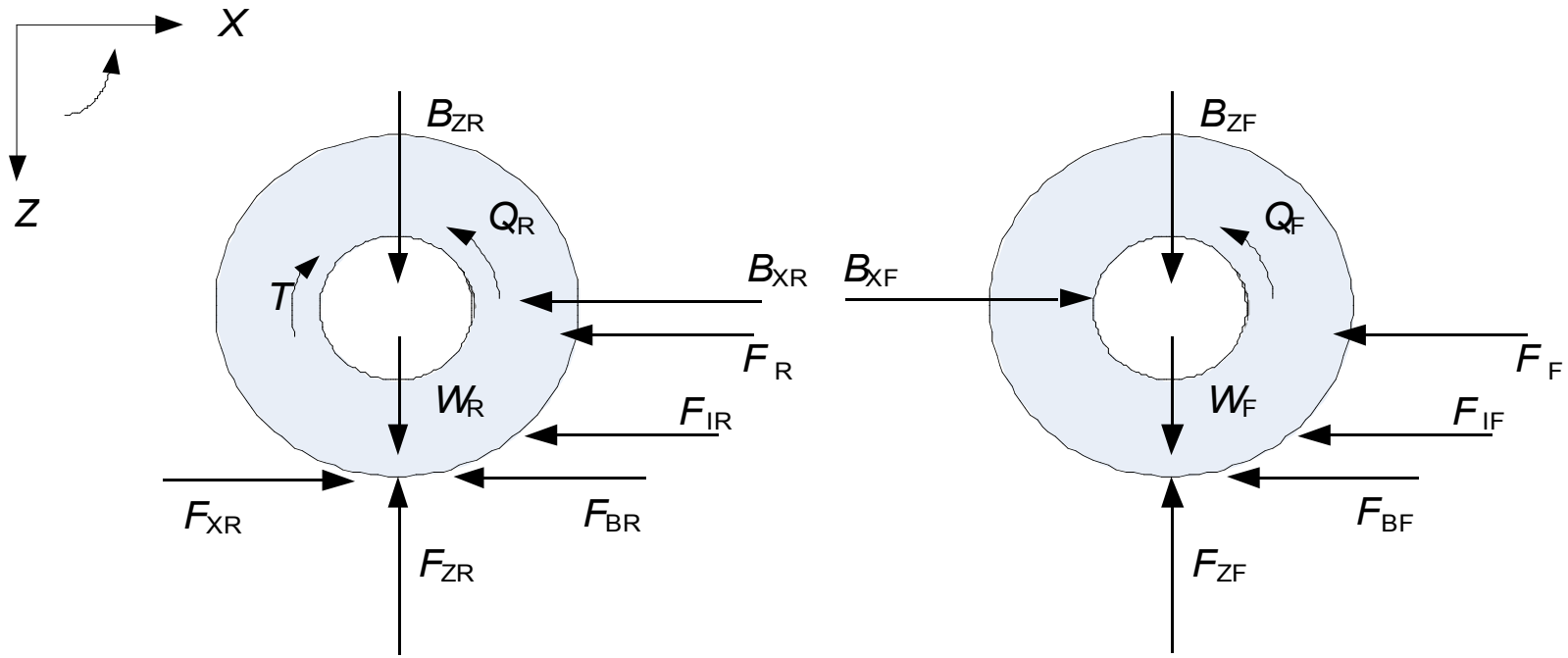
Front-wheel drive any better?

Presenter at play !

Free body diagram equivalent



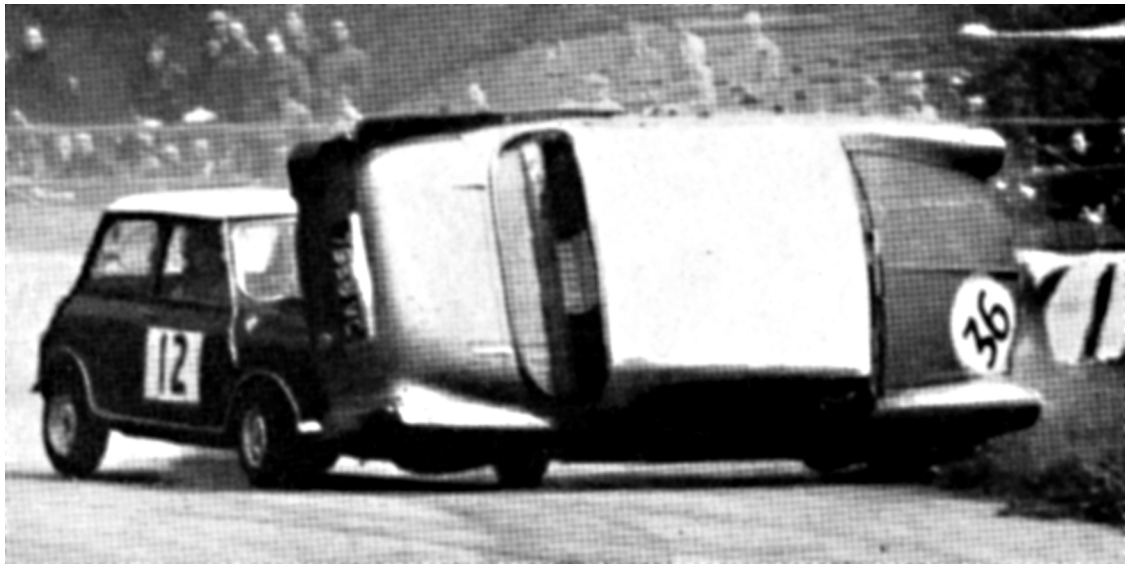
Wheel forces



Under- and oversteer

Cornering above neutral steer

When it goes wrong…



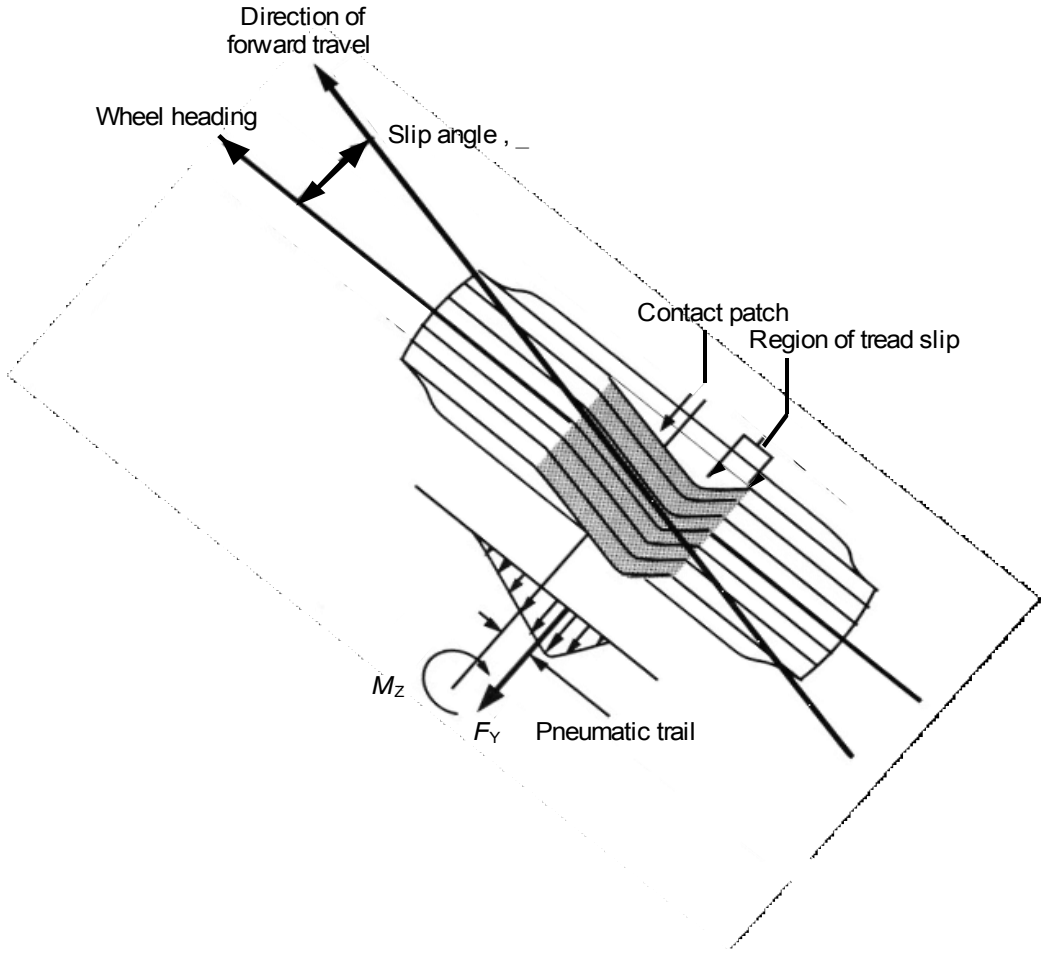
$$\ddot{y} = (N_A + 1)\frac{gt_r}{2h} - (F_{ZFL} + F_{ZRL})\frac{t_r}{mh}$$ **Skidding**

$$\ddot{y} = \pm(N_A + 1)\frac{gt_r}{2h}$$ **Rollover**

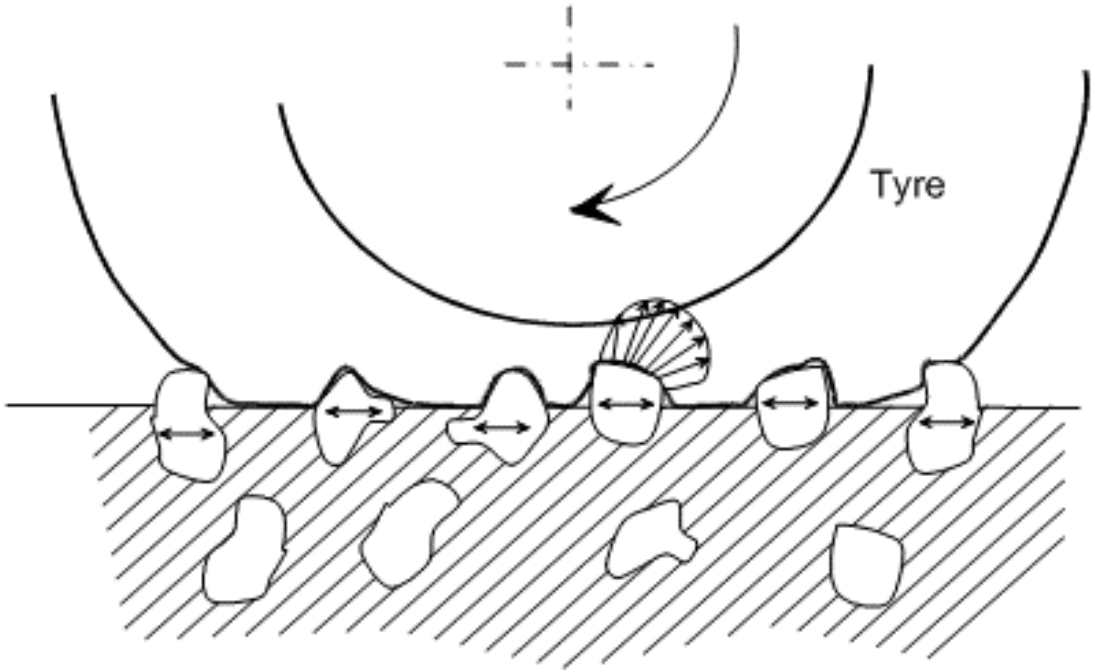
Tyre cross-section

In action…

Start with slip angles



Mechanisms of grip

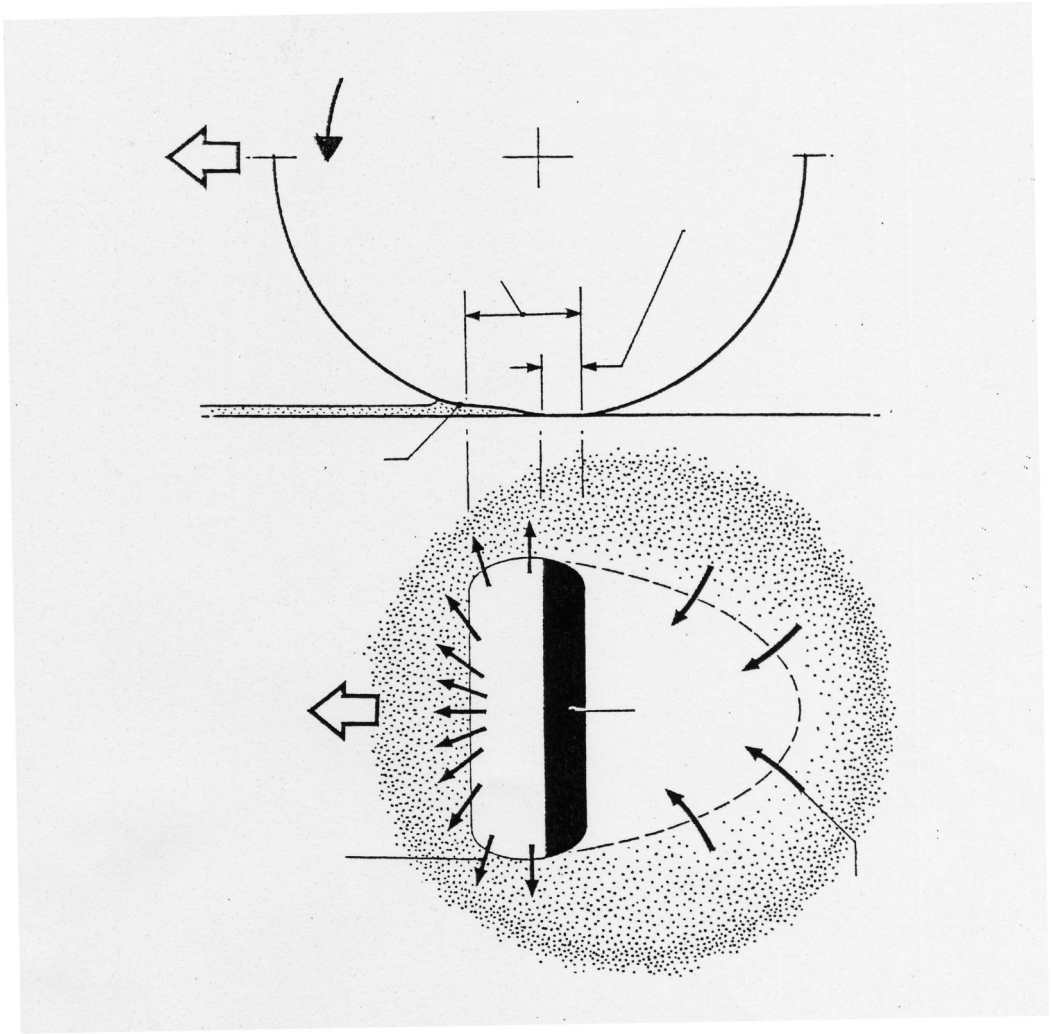


Simple friction;

Mechanical purchase;

Chemical bonding

Dealing with wet road surface



Considerations

Cornering stiffnesses and coefficients;

Slip angles;

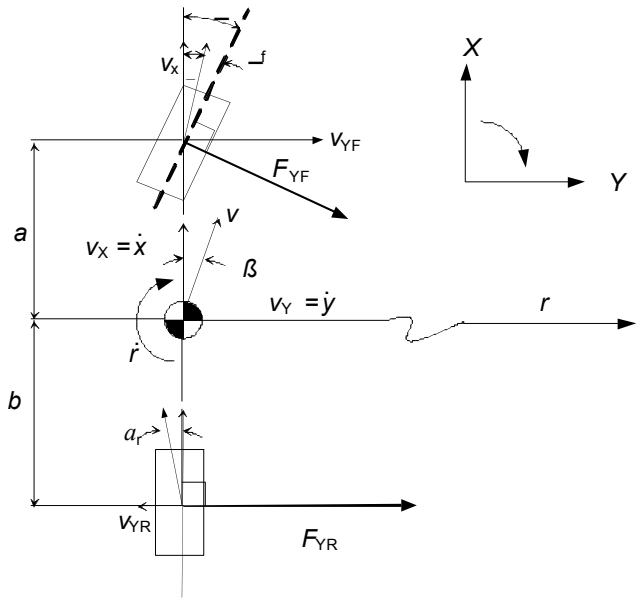
Camber stiffnesses and coefficients;

Friction circles and g-g diagrams;

Performance testing;

Magic tyre formula;

Equations of motion



$$mv\left(\dot{r}+\dot{\beta}\right)=\left(C_{\text{áF}}+C_{\text{áR}}\right)\beta+C_{\text{áF}}\frac{\dot{r}a}{v}-C_{\text{áR}}\frac{\dot{r}b}{v}-C_{\text{áF}}\delta$$

$$I_Z\ddot{r}=\left(C_{\alpha\text{F}}a-C_{\alpha\text{R}}b\right)\beta+\frac{\dot{r}}{v}\left(C_{\alpha\text{F}}a^2+C_{\alpha\text{R}}b^2\right)-C_{\alpha\text{F}}a\delta$$

Derivatives approach

$$\Delta\left(mv\left(\dot{r}+\dot{\beta}\right)\right)=\left(\frac{\partial Y}{\partial \beta}\right)\beta+\left(\frac{\partial Y}{\partial r}\right)\dot{r}+\left(\frac{\partial Y}{\partial \delta}\right)\delta$$

$$\Delta I\ddot{r}=\left(\frac{\partial N}{\partial \beta}\right)\beta+\left(\frac{\partial N}{\partial r}\right)\dot{r}+\left(\frac{\partial N}{\partial \delta}\right)\delta$$

$$Y_{\hat{a}}=C_{\acute{a}F}+C_{\acute{a}R}$$

$$Y_{R}=\frac{1}{v}\left(C_{\acute{a}F}a-C_{\acute{a}R}b\right)$$

$$Y_{\ddot{a}}=-C_{\acute{a}F}$$

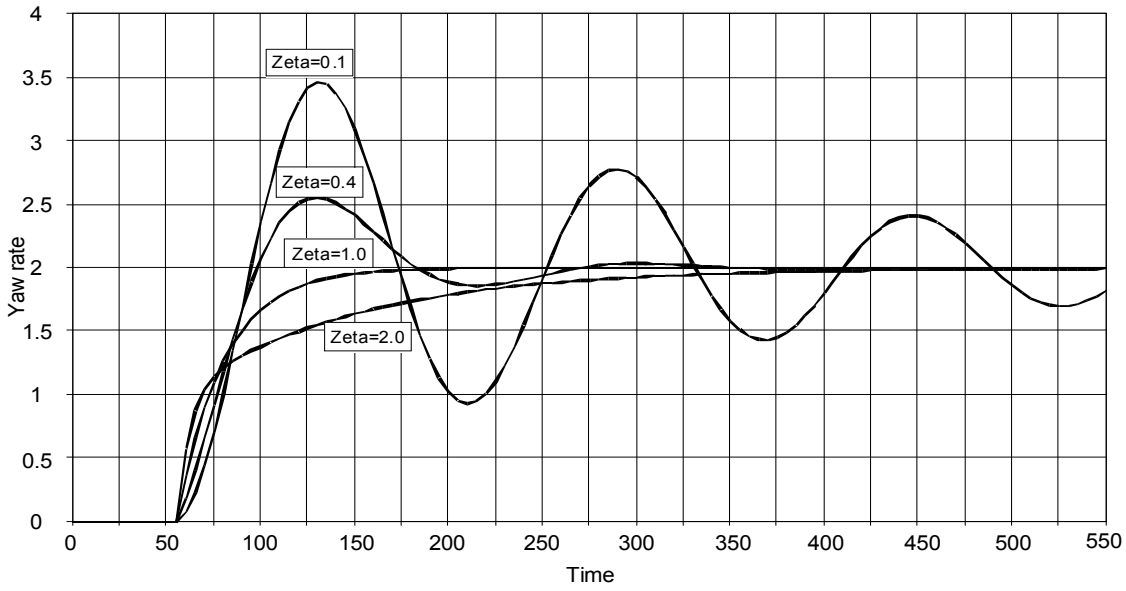
$$N_{\hat{a}}=C_{\acute{a}F}a-C_{\acute{a}R}b$$

$$N_{R}=\frac{1}{v}\left(C_{\acute{a}F}a^{2}-C_{\acute{a}R}b^{2}\right)$$

$$N_{\ddot{a}}=-C_{\acute{a}F}b$$

Each of these six derivative terms, has an understandable physical role to play in the dynamics of the vehicle.

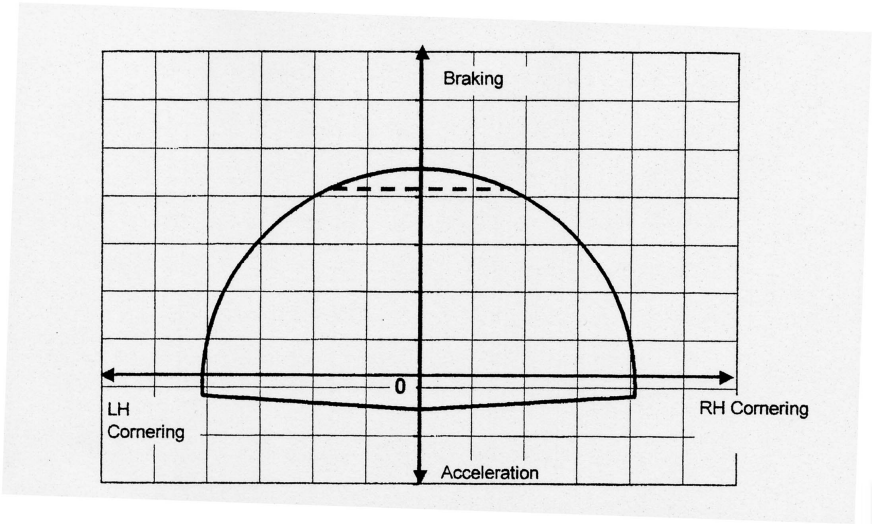
Derived yaw rates

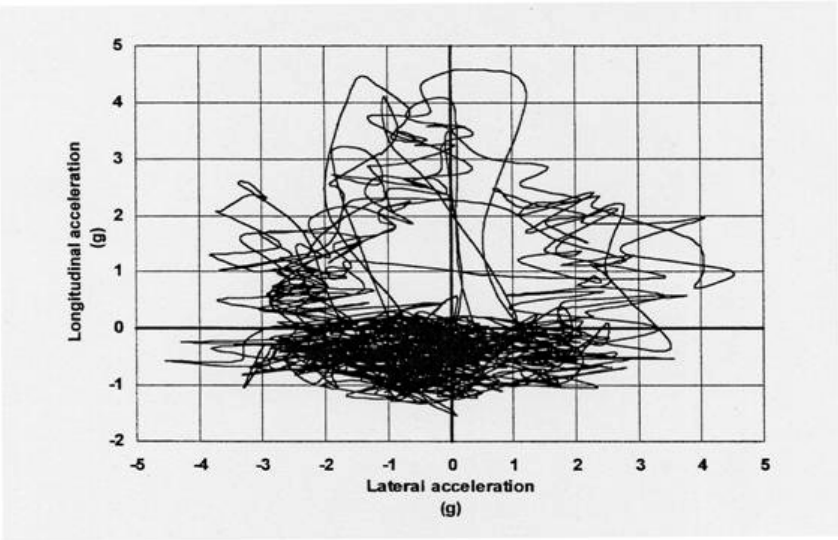


This is the best explanation of derivatives I have seen!

Pat Symonds, former Executive Director of Engineering, Renault F1

G-g ‘friction circle’ (modified)





Cornering issues

Limit performance cornering;

Dynamic responses, oversteer and understeer;

Understeer gradient – effects of mass centre, camber, weight transfer, differential, anti-roll bar stiffness.

Suspension mechanics

Steering issues

Ackermann and anti-Ackermann;

King pin inclination;

Camber and compensation;

Castor;

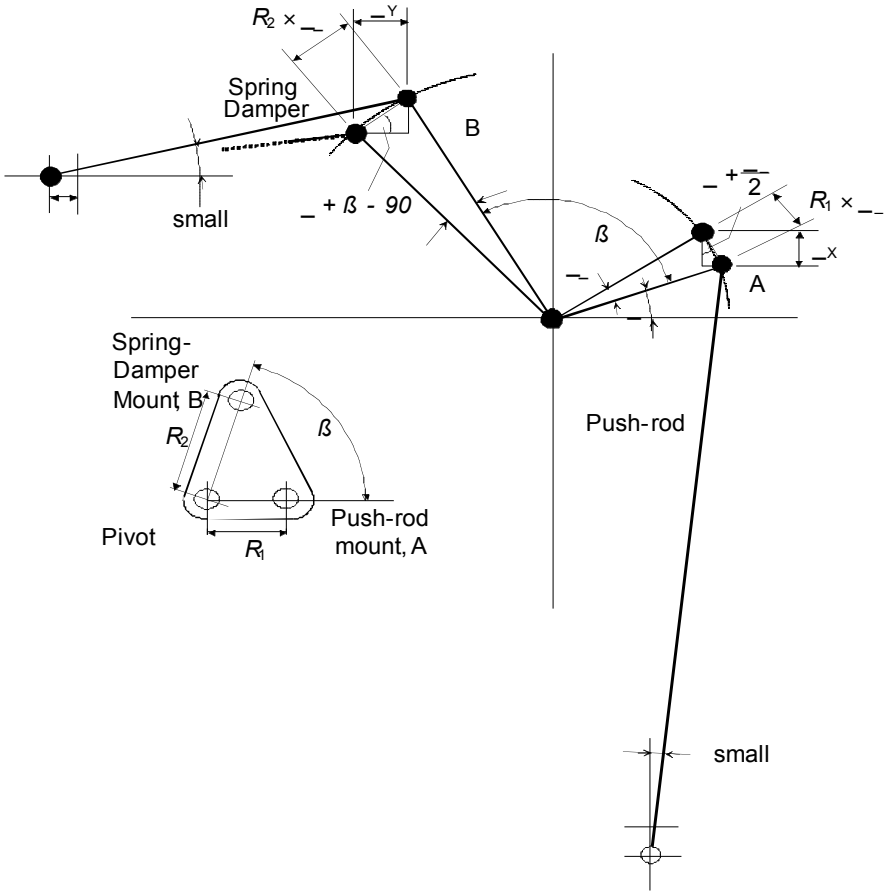
Trail;

Offset;

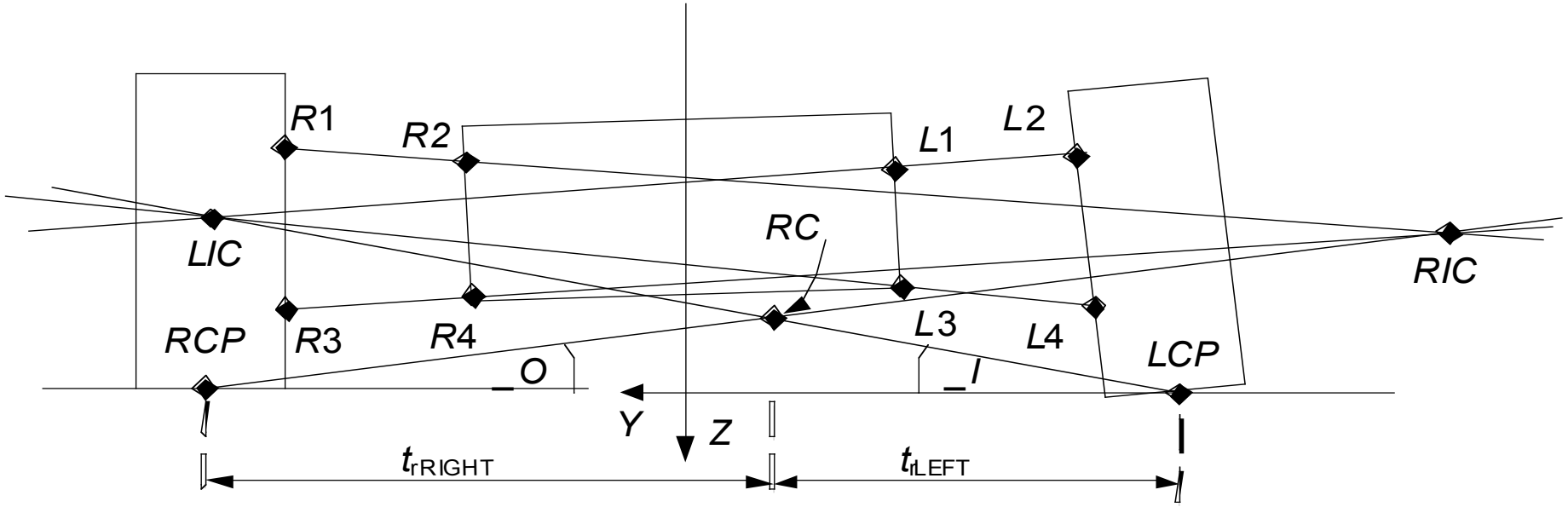
Scrub;

Bump and toe steers

Suspension kinematics

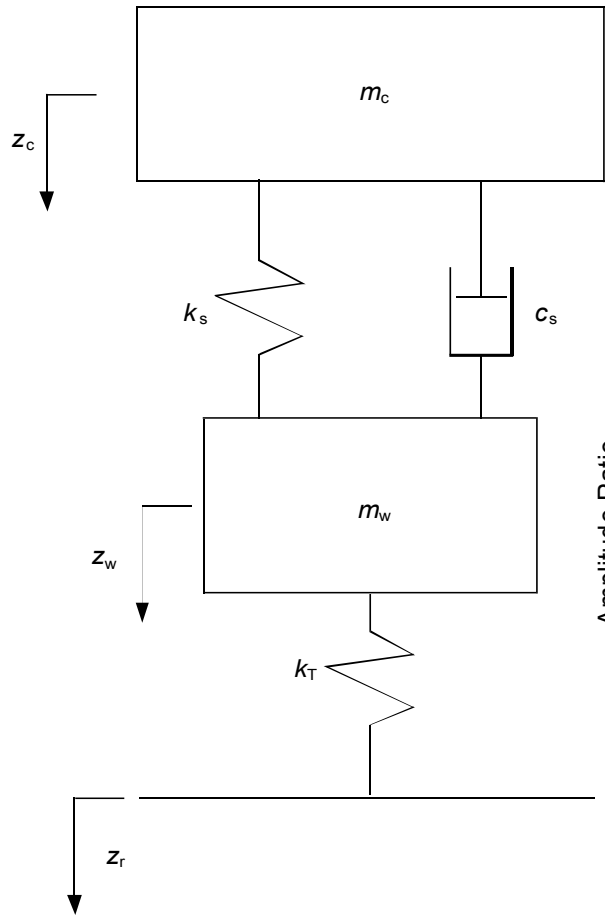


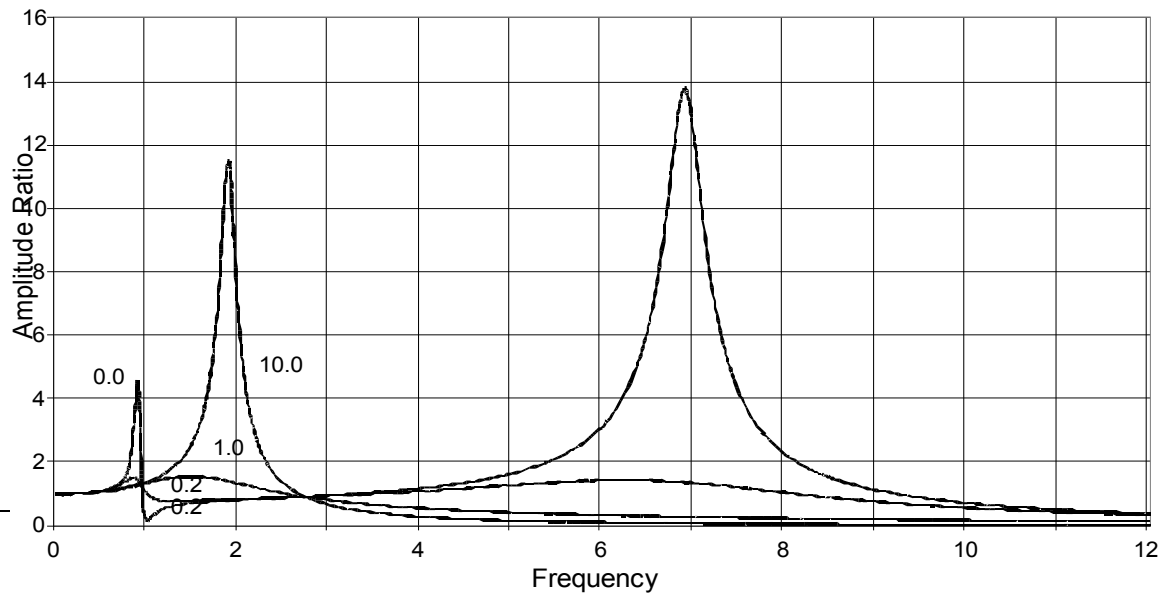
Roll centre migration



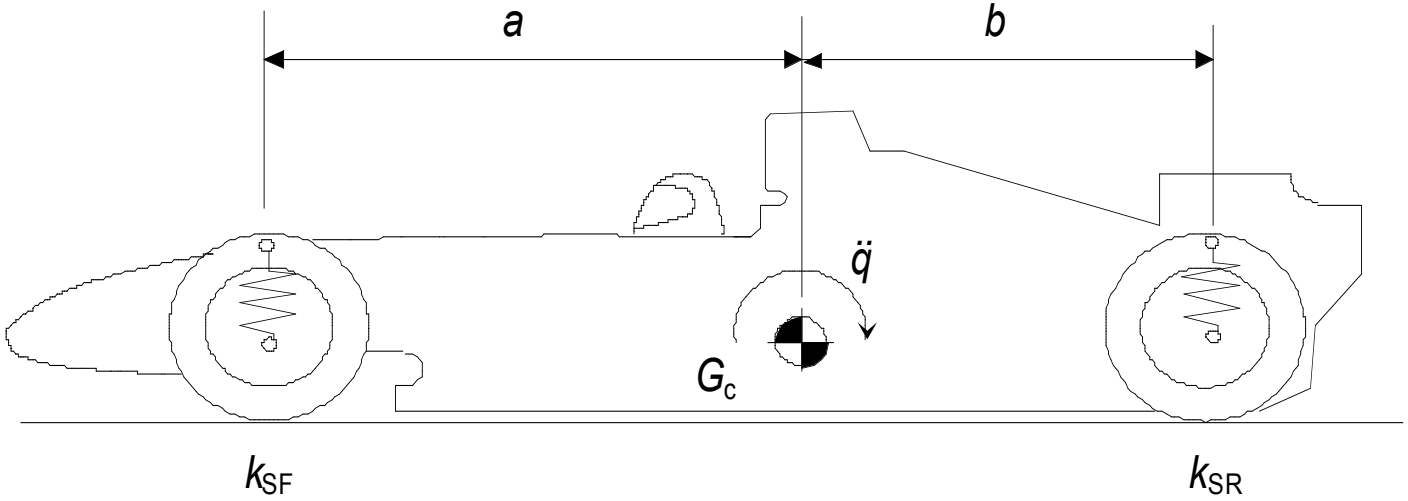
$$RC(y) = RCP(y) + \frac{LCP(y) - RCP(y)}{1 + \frac{RIC(z)\left(LCP(y) - LIC(y)\right)}{LIC(z)\left(RIC(y) - RCP(y)\right)}}$$

Selection of spring and optimum damper values – ¼ car model





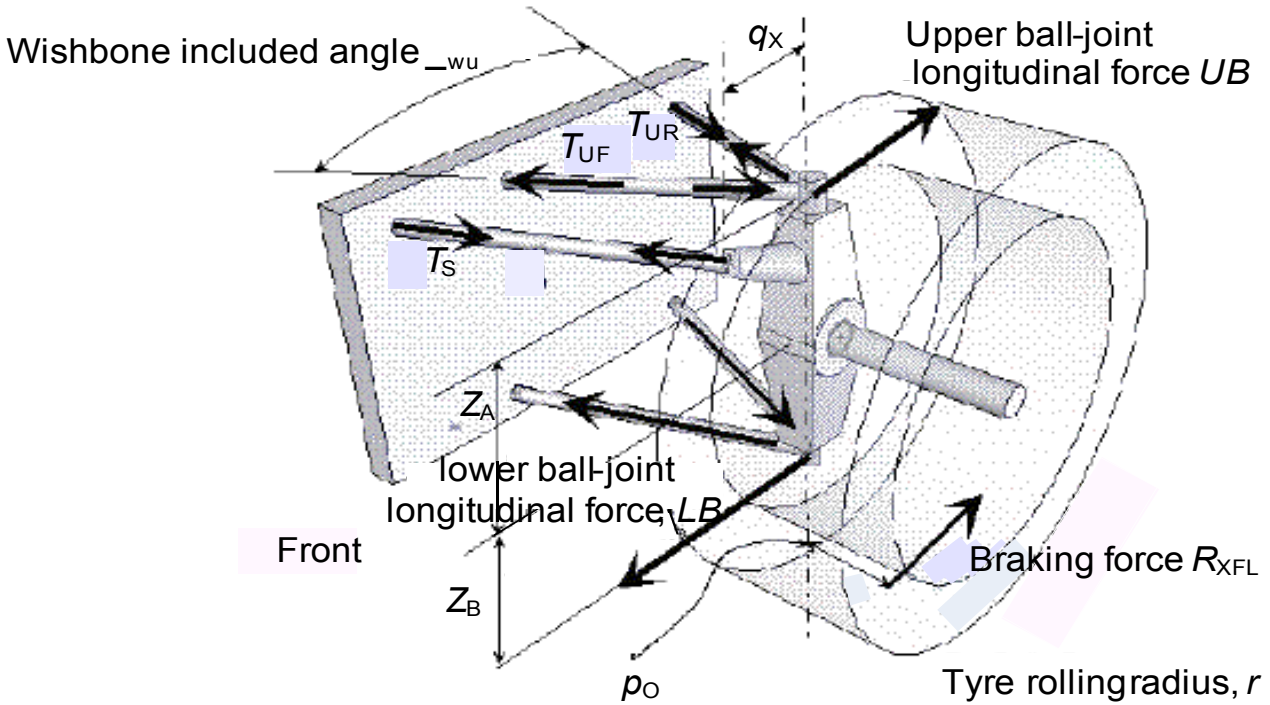
Heave and pitch – coupled and uncoupled motions



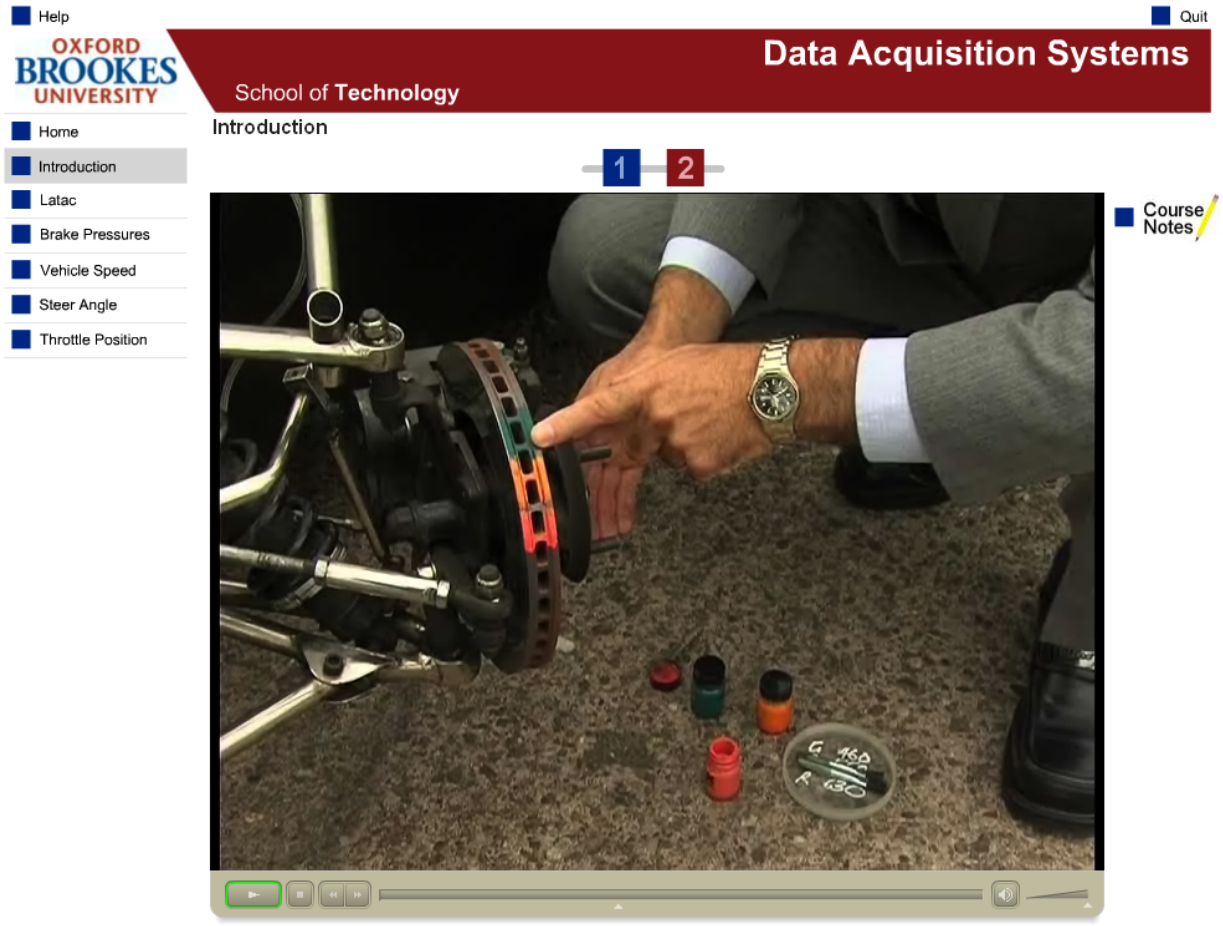
$$(m_C I_{YC})\omega_n^4 - \left[k_{SF}\left(I_{YC} + m_C a^2\right) + k_{SR}\left(I_{YC} + m_C b^2\right)\right]\omega_n^2 + k_{SF}\, k_{SR}\,(a+b)^2 = 0$$

(need help with rallying!)

Forces in suspension members – F1 load cases



A traditional data acquisition system!



Four strands

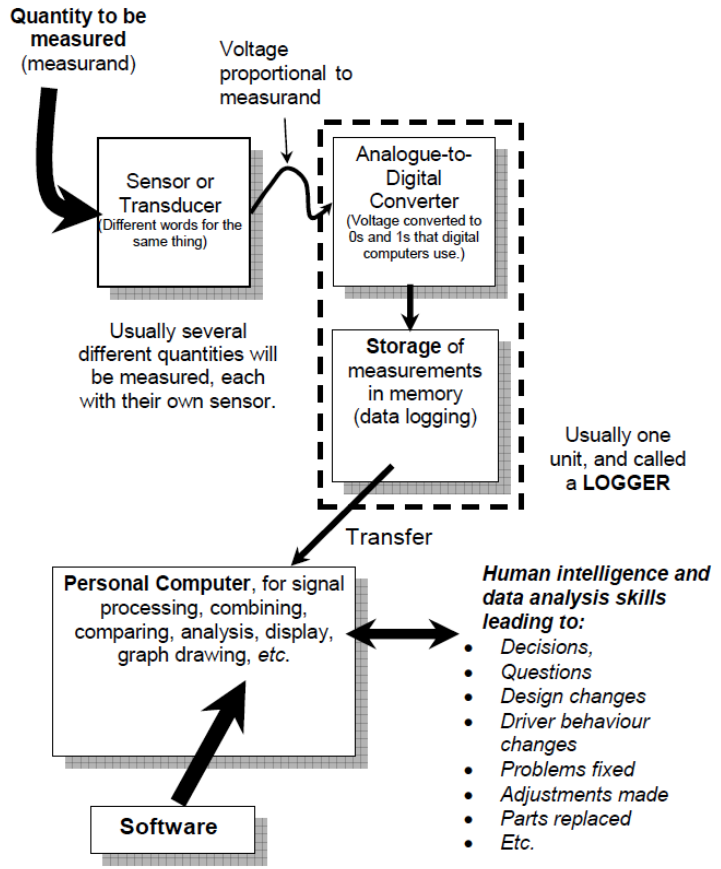
1) Sensors and systems, how they work, background theory, accuracies;

2) Fitting sensors, storage units, cabling, testing, calibrations;

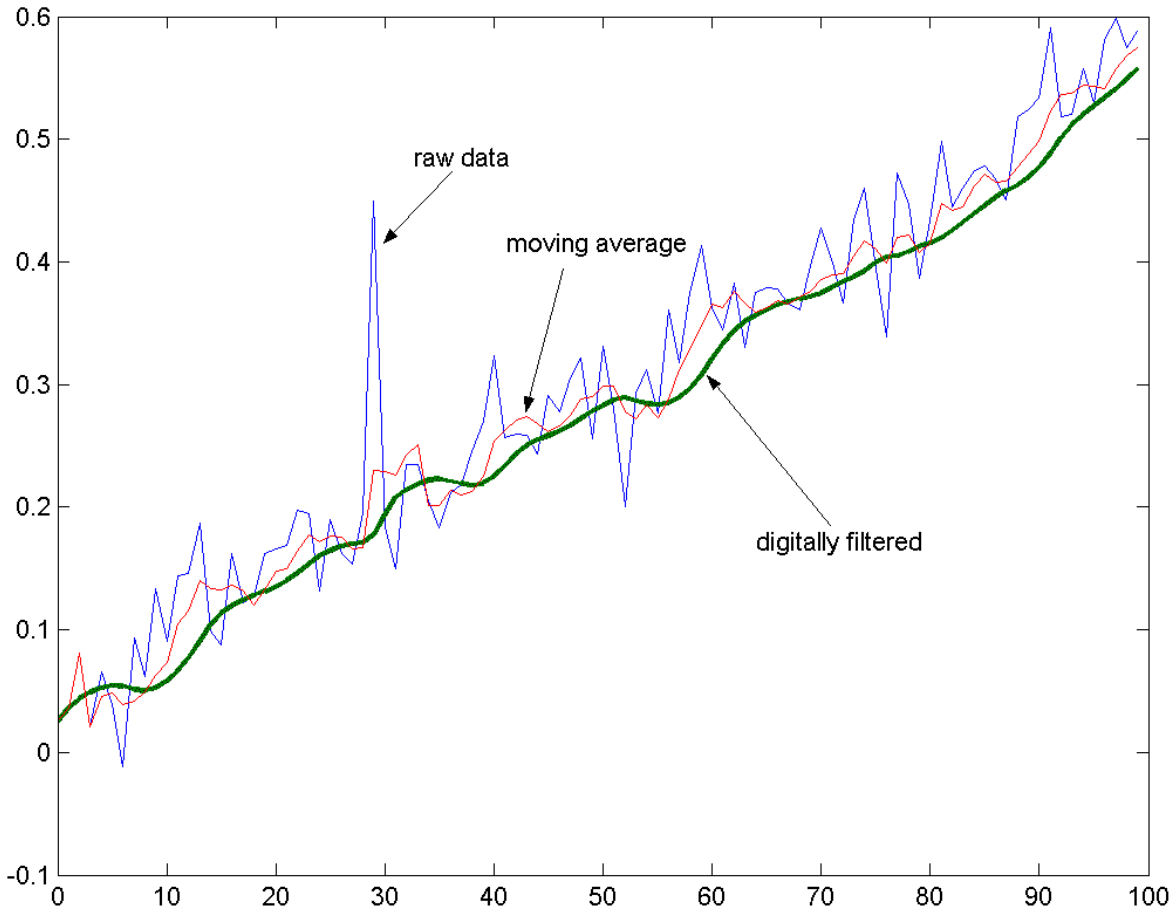
3) Interpreting the data, reading traces, overlays, maths channels;

4) ‘Doing something’ - make changes to car and compare results.

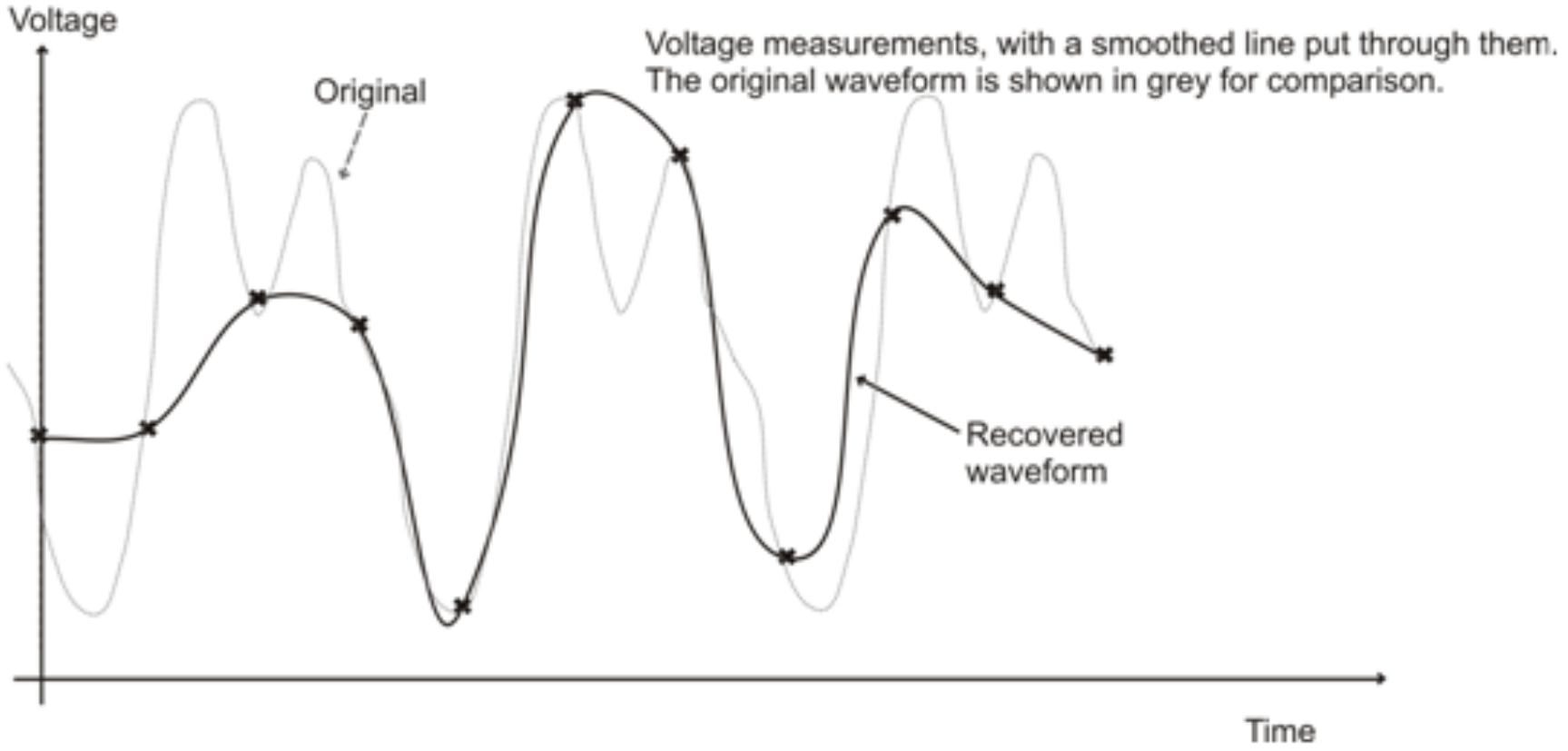
The system


Quantity to be measured (measurand)
Voltage proportional to measurand
Sensor or Transducer (Different words for the same thing)
Analogue-to-Digital Converter (Voltage converted to 0s and 1s that digital computers use.)
Usually several different quantities will be measured, each with their own sensor.
Storage of measurements in memory (data logging)
Usually one unit, and called a LOGGER
Transfer
Personal Computer, for signal processing, combining, comparing, analysis, display, graph drawing, etc.
Human intelligence and data analysis skills leading to:
Decisions,
Questions
Design changes
Driver behaviour changes
Problems fixed
Adjustments made
Parts replaced
Etc.
Software

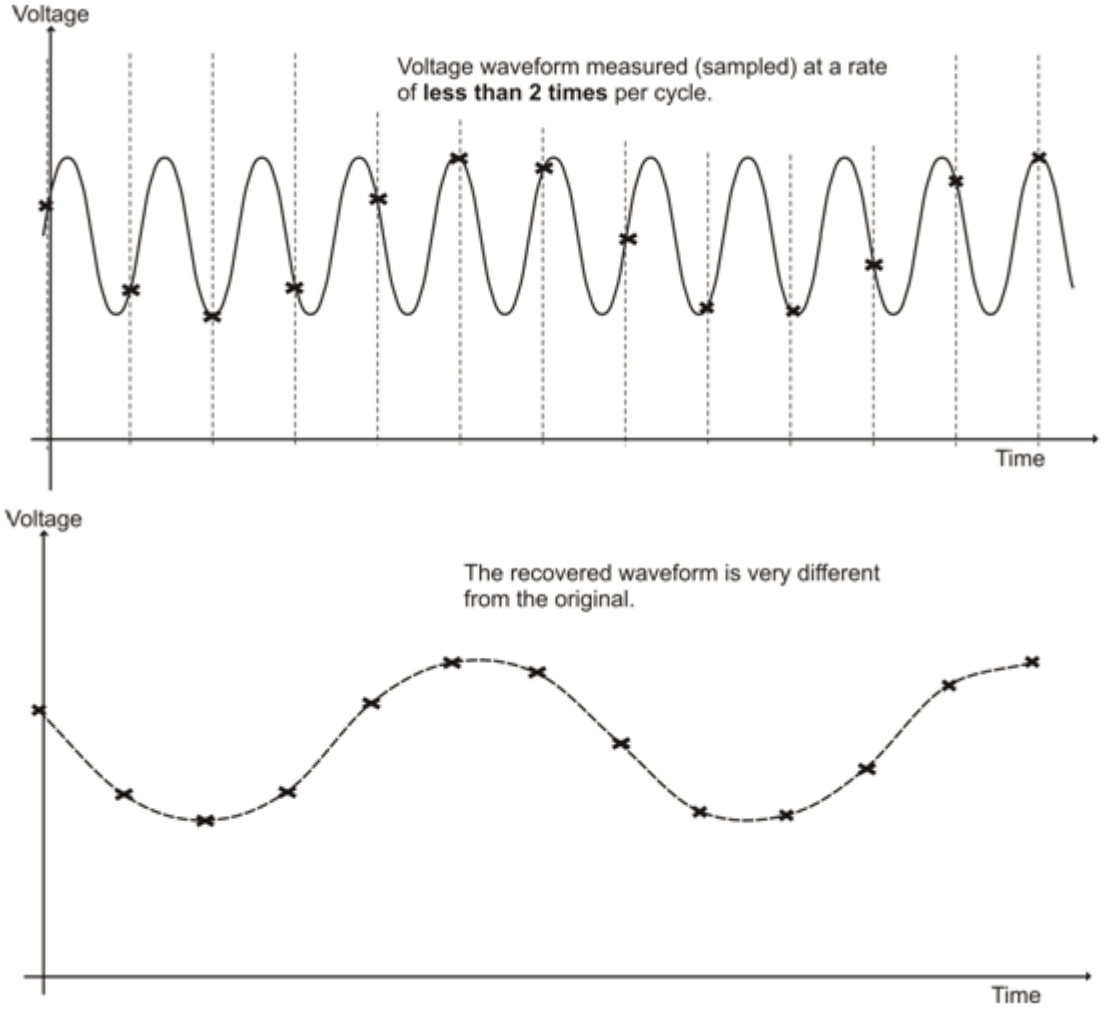
Effects of filtering data



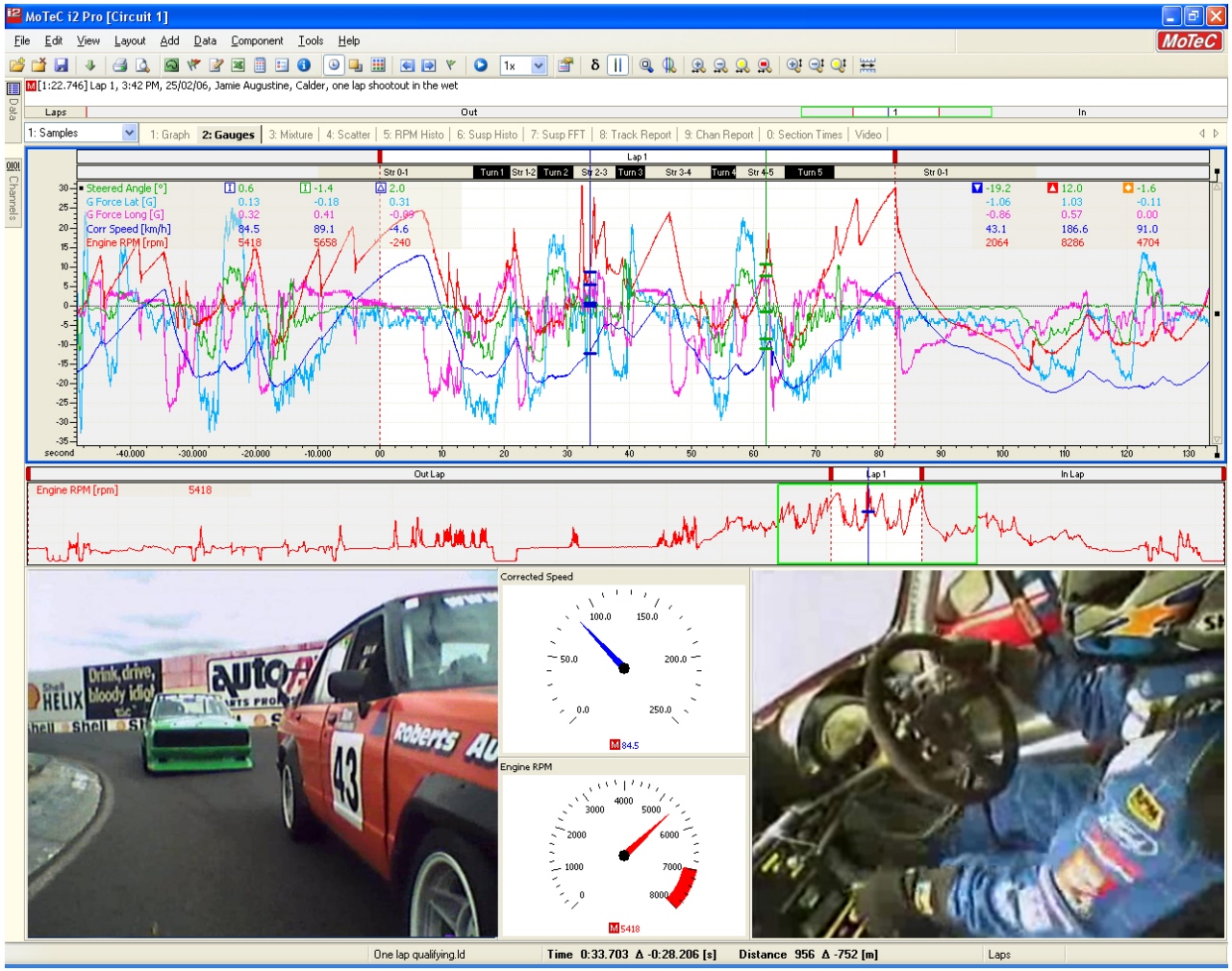
Determining minimum sampling rates for frequencies



The problem of aliasing



Sort out some real data!



New course – Business for Motorsport

- About *business, innovation, entrepreneurship,* and *management* in the motorsport industry – decision making, visualisation, project management, entrepreneurship, understanding business context, interpersonal and communication skills. The cluster will benefit. [Govt. report].

- Predominantly online, but three seminars moderated by industry experts, provide critique/contemporary relevance.

- Intention - to facilitate fast-track transition from *Engineer* to industry-ready *Business Development Manager;*

And…

- To provide budding entrepreneurs with the tools necessary to start up a successful small motorsport business

The future overall

- A complete industry-focused, market-driven, flexibly-delivered Motorsport Engineering and Management MSc achievable solely through distance/blended learning (Sept. 2010 onwards)
- Expanding course portfolio to include '*Advanced Data Acquisition/Data Analysis*' '*Material Science for Motorsport'*, '*Motorsport Aerodynamics', 'Race Engineering'*, and '*Racing Engine Design'* amongst others
- Franchising of courses to overseas institutions, particularly in the US, Australia, and the Middle and Far East
- Further enhancement of motorsport teaching and research environment from investment of course revenue streams
- **Impact of green motor sport issues:** EEMS (UK); Green Racing Working Group (USA)

Motorsport CPD programme thus far - an industry view…

'Very good – makes me want to be back at University'

Dr. Pat Symonds, *former Executive Director of Engineering, RenaultF1*, (evaluating the *Data Acquisition* draft material)

More reviews (Chassis)…

- '*Well written and very informative. The basic 'philosophy' of Pat [Symonds] shows through which I think is really important and one of the best values you have. He adds practicality to the courses which counts for a lot*.' **Mark Preston, Technical Director, Formtech Composites, former Technical Director, Super Aguri F1**

- *'I was very impressed by the quality of the courses. I liked the layout and it is very easy for the reader as there was a good balance of equations, physical explanations, and useful figures. The amount of work is very impressive.'* **Thomas Wissart, Senior Engineer, Performance Analysis Simulation and Performance Analysis, Toyota Motorsport GmbH, former R&D Engineer in charge of tyre data analysis, Super Aguri F1**

- *'These courses will probably become the reference for many people'.* **Ben Michell, Senior Design Engineer-Car, Dunlop Motorsport**

- *'Well laid out with a sensible progression of topics.'* **Dr. Nick Treverrow, Senior Vehicle Dynamics Engineer, Australian Road Research Board, former HondaF1**

More reviews (Chassis)…

More reviews (Data)…

- *'My personal view is that this looks fantastic and that it could be very useful for those guys who fringe on the racing ends of things, especially with the boot camp!'* **Steve Nevey, Business Development Manager, Red Bull Technology**
- *'I think that it is a well put-together course. Easy to follow and instructive at the same time*'. **Dr. Peter Van Manen, CEO, McLaren Electronics**
- *'I am really enjoying this course so far and want to commend you guys on your efforts'.* **Wayne Gross, US-based Race Support Engineer**
- *'When can I sign up'!* **Prof. Tad Foster, former Dean of the Faculty of Engineering, Indiana State University**
- *'The overall coursework material is excellent and well prepared'.* **Peter Jackson, General Manager, MoTeC (Europe)**
- *'I studied this course because I wanted to gain employment in motorsport – and it worked'!* **Darren Shepherd, former student**

Thank you for your attention – any questions?

赛车冠军真棒！

It was awesome!