Vehicle Tuning

Kaz Technologies

Who's your presenter?

- ## Jim Kasprzak

- 36 years racing experience

- Developed 7-post testing for GM Racing

- Currently Race Engineer for SRT Viper

- Expertise includes:
  - Race Engineering
  - 7 post testing
  - Suspension Engineering
  - Shock design, development, & tuning
  - Vehicle Tuning

- 31 years automotive experience
  - Arvin Ride Control
    - Director, Original Equipment Engineering
    - Director, New Product Development
  - Monroe Auto Equipment
    - Chief Engineer, Electronic Systems
    - Manager, Suspension System Programs

Outline

- **Preparation for Track Testing**

- **Data Acquisition**
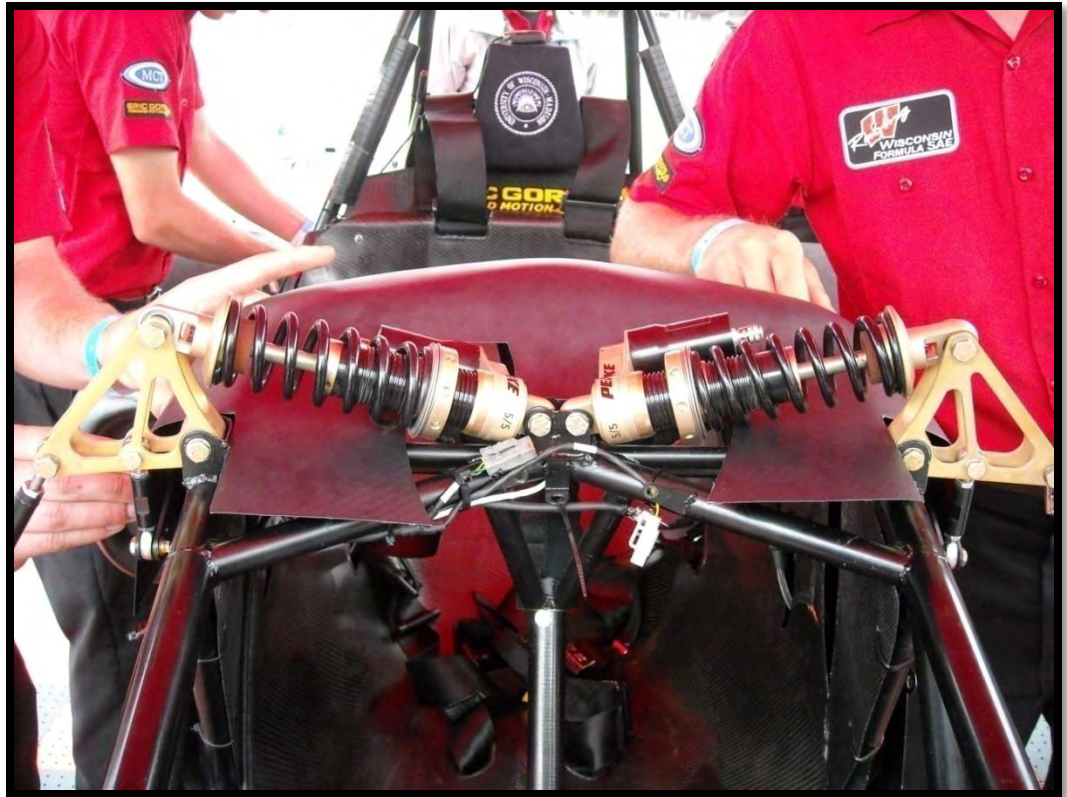
- **Track Testing**

Preparation for Track Testing

Preparation for Testing

- Vehicle Setup
- Damper fit check
- Suspension Setup
- Setup Sheet
- Checklists

Vehicle Setup

- **Engine**
- **Gearbox & Drivetrain**
- **Electrical/Electronics System**
- **Data Acquisition System**
- **Suspension**
- **Brakes**
- **Aero**

Damper Fit Check

Fit Check on Vehicle

Make sure shocks fit correctly!

- Correct travels
  - Shock and spring
- Check jounce bumper engagement
- No binding or interferences

Positioning Shock Travel

Must properly position shock at ride height

- Typically mid stroke at ride height
- Determine shock travel on track
  - Use data acquisition
    - Check for bottoming/topping
  - Use travel indicator on shock rod

Suspension Setup

- **With driver and fuel weight**

- **Bumpsteer**

- **Ride heights & corner weights**

- **Camber, caster, toe settings**

- **Corner weights**

- **Damper adjustments**

Vehicle Set-up Sheet

Event Information

Chassis Information

Packer Gap

Aero Information

Gearbox Information

Session Tabs

Daytona Prototype Chassis Setup

RILEY TECHNOLOGIES

Track	Laguna	Event	Race	Date	5/17/08
Driver	JM MG	Chassis	L-028	Engine	
				Session	Race
				Miles	0

| Split Len | Full | Split Ang | 0.0 | Diveplane | BIG | S Flap | Big | Louver | 12+kicker | S Boxes | Yes |

Camber	-3.1	LF Sidepod	1.881	Ride Hgt	1.820	Ride Hgt	1.822	RF Sidepod	1.886	Camber	-3.4
Caster	9.50	Split Ht	1.575	F AR Bar	1.38	Split Min Ht	1.599	Split Ht	1.575	Caster	9.50
Toe	0.161o			L Blade	50	R Blade	50			Toe	0.162o
				Droop Lim	na	Droop Lim	na				
Code	Pirelli D2			LF Spring	800	RF Spring	800			Code	Pirelli D2
Dia.	26.12			Wheel Rt.	648	Wheel Rt.	648			Dia.	26.12
Setup PSI	30			Shocks	Pen	Shocks	Pen			Setup PSI	30
Cold PSI	18			Shock ID	Riley 5	Shock ID	Riley 6			Cold PSI	18
Hot PSI	28			File	Kaz 17	File	Kaz 17			Hot PSI	28
				Bump Rbr	Ohl 03	Bump Rbr	Ohl 03				
Rake In	0.689	Packer	0.188	Pack Gap	0.530	Pack Gap	0.498	Packer	0.188	Tilt Deg	0.00
Rake Deg				Gas Pres	150	Gas Pres	150				
				Set	-15+3-12	Set	-15+3-12				

| | | F Scoop | Open | F Press | | F Mast | 810 | F Rot | 252 | F Pad | Pagid rs5 |
| | | R Rest | 1.25 | R Press | | R Mast | 810 | R Rot | 252 | R Pad | Pagid rs5 |

Setup Fuel	15g	Driver	175	LF Wgt	597	RF Wgt	602	Setup Wgt	2596	Wedge %	49.88
Start Fuel	15g	Body On?	N	LR Wgt	693	RR Wgt	704	Tech Wgt	682	Front %	46.19
Fuel Wgt	95.10									Right %	50.31
Sidepod	2.290	SPod Raise	0.015	Ride Hgt	2.510	R AR Bar	0.500	S pod Raise	0.015	Sidepod	2.290
				Rock Link	no	Blade	Soft				
Camber	-1.6			LR Spring	1050	RR Spring	1050			Camber	-1.7
Toe	0.060i ?			Wheel Rt.	723	Wheel Rt.	723			Toe	0.060i ?
				Shocks	Pen	Shocks	Pen				
Code	Pirelli D2			Shock ID	Riley 7	Shock ID	Riley			Code	Pirelli D2
Dia.	27.49			File	RT 1	File	RT 1			Dia.	27.49
Setup PSI	30			Bump Rbr	Ohl 03	Bump Rbr	Ohl 03			Setup PSI	30
Cold PSI	18	Packer	0.000	Pack Gap	1.360	Pack Gap	1.410	Packer	0.000	Cold PSI	18
Hot PSI	28			Gas Pres	150	Gas Pres	150			Hot PSI	28
				Set	-10+6-11	Set	-10+6-9				

| Main ang | 18.50 | Gurney | 0.750 | Spoiler ang | 35.00 | Sp Gurney | 2.000 | S Board | No | Sp hole | Center |
| | | Uncut - No Taper | | | | Sp Ext Ht | 1.000 | | | | |

R&P	12 : 36	Drop	1 : 1	Avg R Dia	27.49	RPM	7,100	Diff	50 pl+AA	6 plate X-Trac
1st	14 : 35	2nd	16 : 31	3rd	20 : 33	4th	18 : 26	5th	22 : 28	6th
MPH	77.4		99.9		117.3		134.0		152.1	
Drop	NA		1,598		1,054		885		844	

| Other | V8 steering blocks (Low front roll center)(Low ackerman, Long tie rod) |

9 tooth rack

Copyright Kaz Technologies 2012

Race | 5-17-08 Sess 4 End | 5-17-08 Start | 5-17-08 Setup | | 5-16-08 Sess 2 | 5-16-08 Sess 2 Setup | 5-16-08 Sess

Checklists

Before Each Dynamic Event

- Check fluid levels

- Check for full throttle

- Oil Chain

- Fill with fuel

- Ty-wrap spark plug boots to spark plugs

- Set tire pressures to proper pressures

- Start & warm up engine

- Check to make sure engine temp and oil pressure are normal during engine warm up

Data Acquisition

Data Acquisition Sensors

- **Steering - 25 Hz**

- **Throttle – 20 Hz**

- **Lateral Acceleration - 100 Hz**

- **4 Corner Damper Displacement – 250 Hz**

- **Brake Pressure - 25 Hz**

- **4 Corner Wheel Speed – 100 Hz**

Initial Analysis Page

Speed →

Throttle & Brake →

Steering →

Understeer →

VyDot →
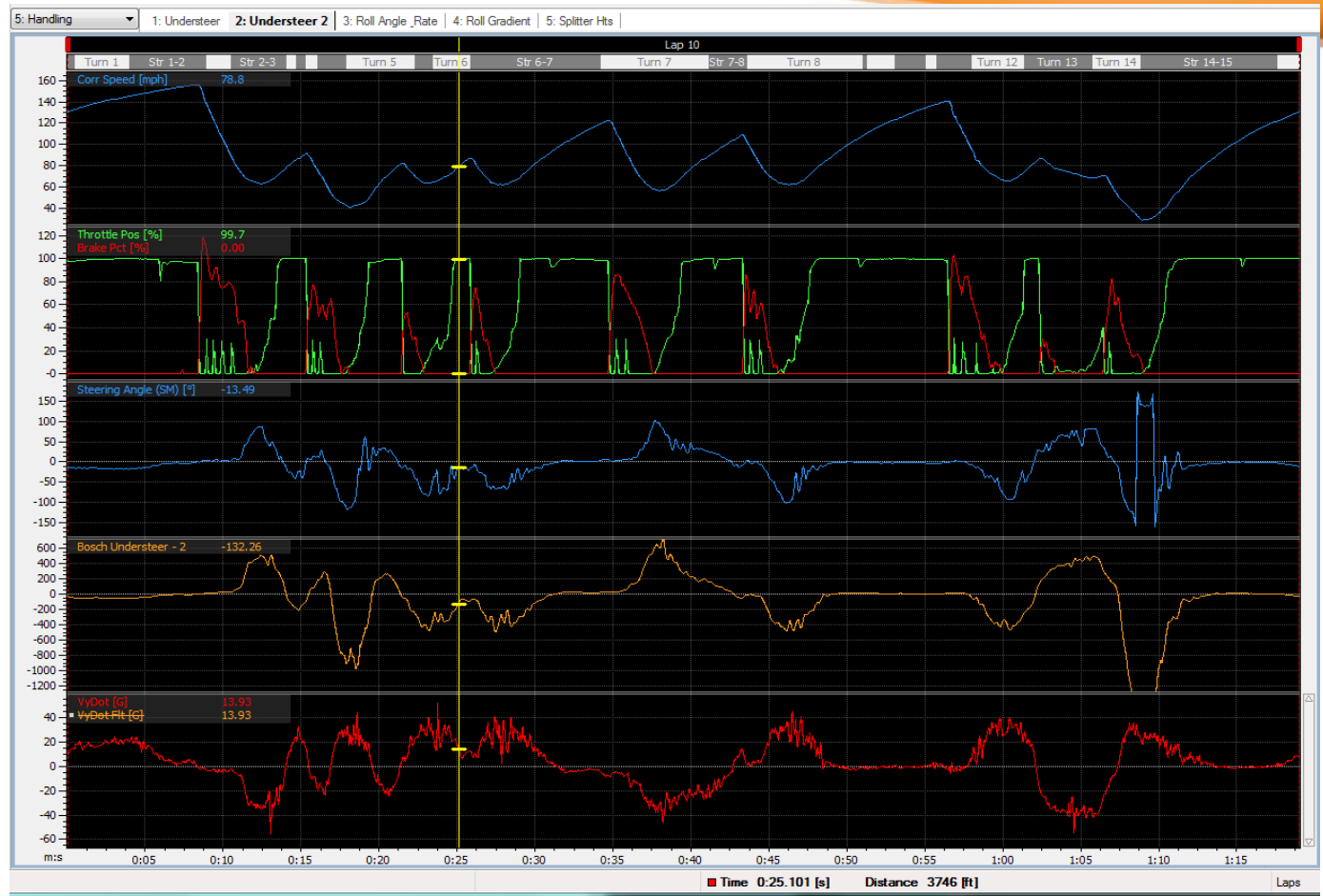
Unfiltered Dampers

Steering

Throttle

Damper Displacement

Damper Velocity

Travel to Jounce Bumper

Jounce Bumper Engagement
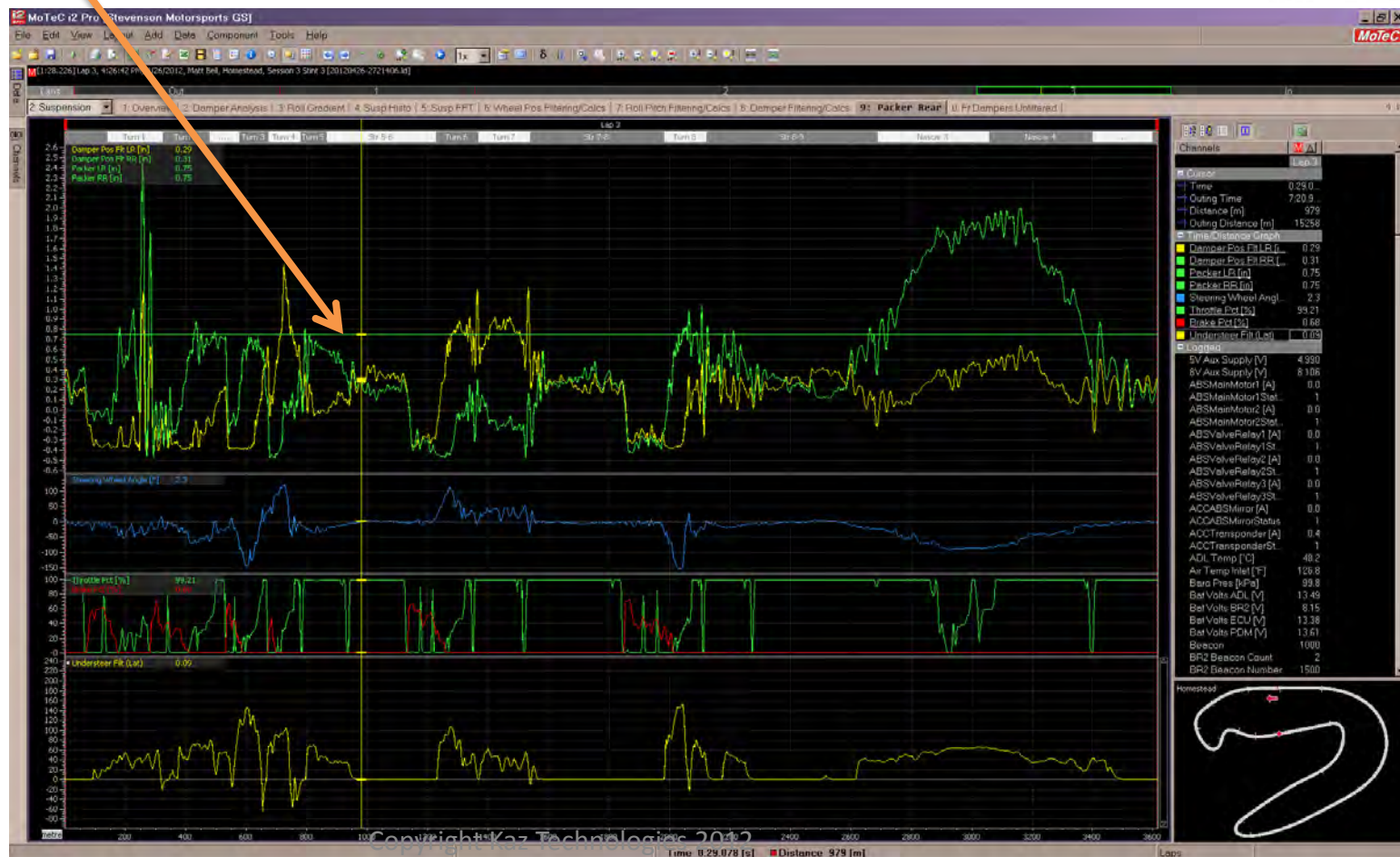
Rear Shocks ⇨

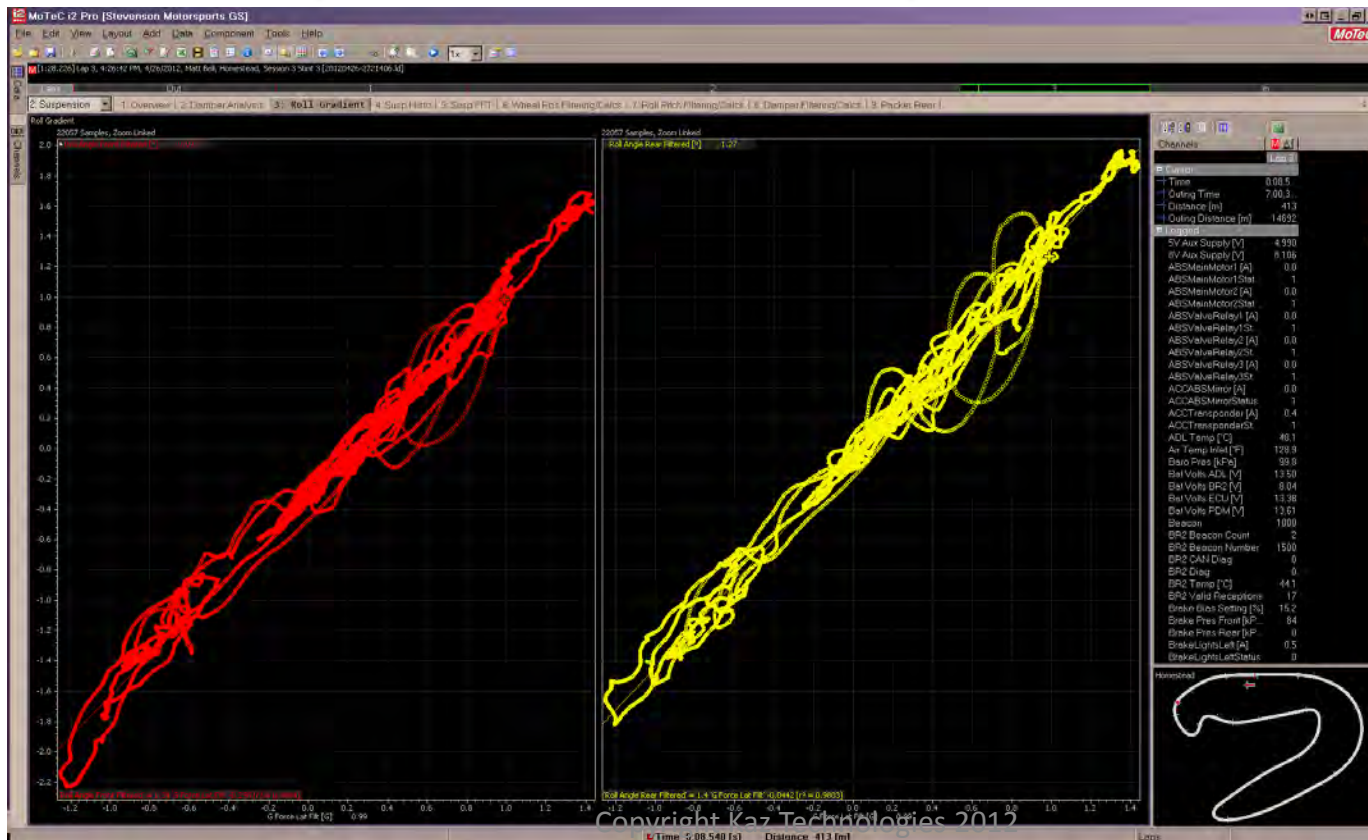Steering ⇨

Throttle Brake ⇨

Understeer ⇨

Roll Gradient

Front Roll Gradient (1.34)   Rear Roll Gradient (1.4)

Track Testing

Track Testing

- Vehicle Setup

- Run Log

- Basic handling

- Damper tuning

- More advanced tuning

- Test summary

Vehicle Set-up Sheet

Event Information

Chassis Information

Packer Gap

Gearbox Information

Aero Information

Session Tabs

Daytona Prototype Chassis Setup

RILEY TECHNOLOGIES

Track	Laguna	Event		Race	Date	5/17/08	Session	Race
Driver	JM MG	Chassis		L-028	Engine		Miles	0

| Split Len | Full | Split Ang | 0.0 | Diveplane | BIG | S Flap | Big | Louver | 12+kicker | S Boxes | Yes |

Camber	-3.1	LF Sidepod	1.881	Ride Hgt	1.820	Ride Hgt	1.822	RF Sidepod	1.886	Camber	-3.4
Caster	9.50	Split Ht	1.575	F AR Bar	1.38	Split Min Ht	1.599	Split Ht	1.575	Caster	9.50
Toe	0.161o			L Blade	50	R Blade	50			Toe	0.162o
				Droop Lim	na	Droop Lim	na				
Code	Pirelli D2			LF Spring	800	RF Spring	800			Code	Pirelli D2
Dia.	26.12			Wheel Rt.	648	Wheel Rt.	648			Dia.	26.12
Setup PSI	30			Shocks	Pen	Shocks	Pen			Setup PSI	30
Cold PSI	18			Shock ID	Riley 5	Shock ID	Riley 6			Cold PSI	18
Hot PSI	28			File	Kaz 17	File	Kaz 17			Hot PSI	28
				Bump Rbr	Ohl 03	Bump Rbr	Ohl 03				
Rake In	0.689	Packer	0.188	Pack Gap	0.530	Pack Gap	0.498	Packer	0.188	Tilt Deg	0.00
Rake Deg				Gas Pres	150	Gas Pres	150				
				Set	-15+3-12	Set	-15+3-11				

| F Scoop | Open | F Press | | F Mast | 810 | F Rot | 252 | F Pad | Pagid rs5 |
| R Rest | 1.25 | R Press | | R Mast | 810 | R Rot | 252 | R Pad | Pagid rs5 |

Setup Fuel	15g	Driver	175	LF Wgt	597	RF Wgt	602	Setup Wgt	2596	Wedge %	49.88
Start Fuel	15g	Body On?	N	LR Wgt	693	RR Wgt	704	Tech Wgt	682	Front %	46.19
Fuel Wgt	95.10									Right %	50.31
Sidepod	2.290	SPod Raise	0.015	Ride Hgt	2.510	R AR Bar	0.500	S pod Raise	0.015	Sidepod	2.290
				Rock Link	no	Blade	Soft				
Camber	-1.6			LR Spring	1050	RR Spring	1050			Camber	-1.7
Toe	0.060i ?			Wheel Rt.	723	Wheel Rt.	723			Toe	0.060i ?
				Shocks	Pen	Shocks	Pen				
Code	Pirelli D2			Shock ID	Riley 7	Shock ID	Riley			Code	Pirelli D2
Dia.	27.49			File	RT 1	File	RT 1			Dia.	27.49
Setup PSI	30			Bump Rbr	Ohl 03	Bump Rbr	Ohl 03			Setup PSI	30
Cold PSI	18	Packer	0.000	Pack Gap	1.360	Pack Gap	1.410	Packer	0.000	Cold PSI	18
Hot PSI	28			Gas Pres	150	Gas Pres	150			Hot PSI	28
				Set	-10+6-11	Set	-10+6-9				

Main ang	18.50	Gurney	0.750	Spoiler ang	35.00	Sp Gurney	2.000	S Board	No	Sp hole	Center
		Uncut - No Taper				Sp Ext Ht	1.000				
R&P	12 : 36	Drop	1 : 1	Avg R Dia	27.49	RPM	7,100	Diff	50 pl+AA	6 plate X-Trac
1st	14 : 35	2nd	16 : 31	3rd	20 : 33	4th	18 : 26	5th	22 : 28	6th
MPH	77.4		99.9		117.3		134.0		152.1	
Drop	NA		1,598		1,054		885		844	
Other	V8 steering blocks (Low front roll center)(Low ackerman, Long tie rod)									

| Race | 5-17-08 Sess 4 End | 5-17-08 Start | 5-17-08 Setup | | 5-16-08 Sess 2 | 5-16-08 Sess 2 Setup | 5-16-08 Sess |

Practice Session Sheet — RILEY TECHNOLOGIES / KAZ TECHNOLOGIES IES

Date	9/18/08		Track Miller	Event Miller Race
Session	2			Drivers Jim Matthews, Marc Goossens, Ryan Hunter-Reay
				2:42.670

Laps Tot/Tires	Lap Times	Lap Time (Sec)	Changes/Comments		
			Tire Set 2 20.5 19.5		
			Stickers 22.0 22.0		
			Changes		
			Tire pressures up		
90.5 F			Rear springs from 1100 to 1150		
15%			Rear spoiler from 2" to 1"		
25.93			Rear brake restrictor from 1.25 to 2.0		
5:27			**Outing 4** Jim In		
15/1	Out		FARB 3 RARB 3 MAP 1		
	2:44.430				
	2:44.040			Track	108
P10	2:42.590		P1 #10 2:38.048	Hot Press 28.2	27.5
	2:43.010			28.0	28.2
	2:43.170		FARB 2		
	In				
			Outing 5 Ryan In		
			RF to 28 psi Hot		
22/8	Out		FARB 2 RARB 3 MAP 1	Track	96
	2:44.560			Hot Press 29.0	29.0
P11	2:40.560		P1 #59 2:37.313	28.9	29.4
P6	2:38.800		P1 #59 2:37.313		
	In				
			Car is a bit of push high and low speed corners center off, power down.		
			flat corners especially		
			Then the car goes loose. But I think that is because of the amount of wheel		
			Platform feels real solid. Just needs a tweek		
			Outing 6 No Bar Setup - No FARB or RARB		
			Fr springs from 850 to 1100		
			Rr springs from 1150 to 1250		
			RR tire press to 29 psi HOT		
27/13	Out		FARB -- RARB -- MAP 1		
P4	2:38.040		P1 #59 2:37.313	Track	96

Session Information

Tire Data

Tire Info

Driver Comments

Changes

Copyright Kaz Technologies 2012

Basic Damper Tuning

➡️ **Low frequency heave, pitch, balance**

➡️ **High frequency (Bumps)**

➡️ **Handling**
- **Steady state**
- **Braking**
- **Turn-in**
- **Mid-Corner**
- **Exit**

➡️ **Rebound and compression adjustments**

Damping Adjustment Data

Dyno Test - Full Adjustment Sweep

Compression

Rebound
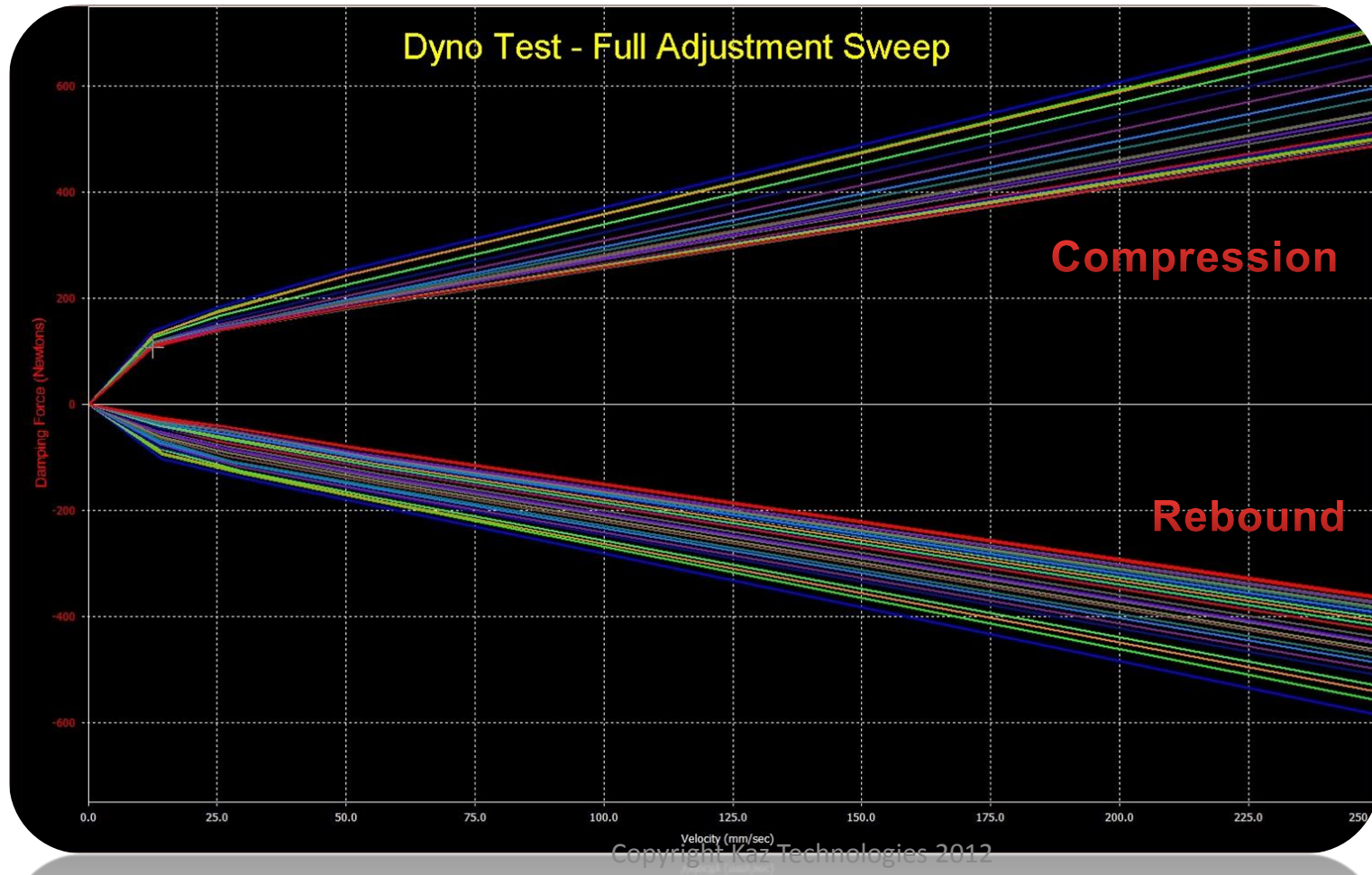
Vehicle Input
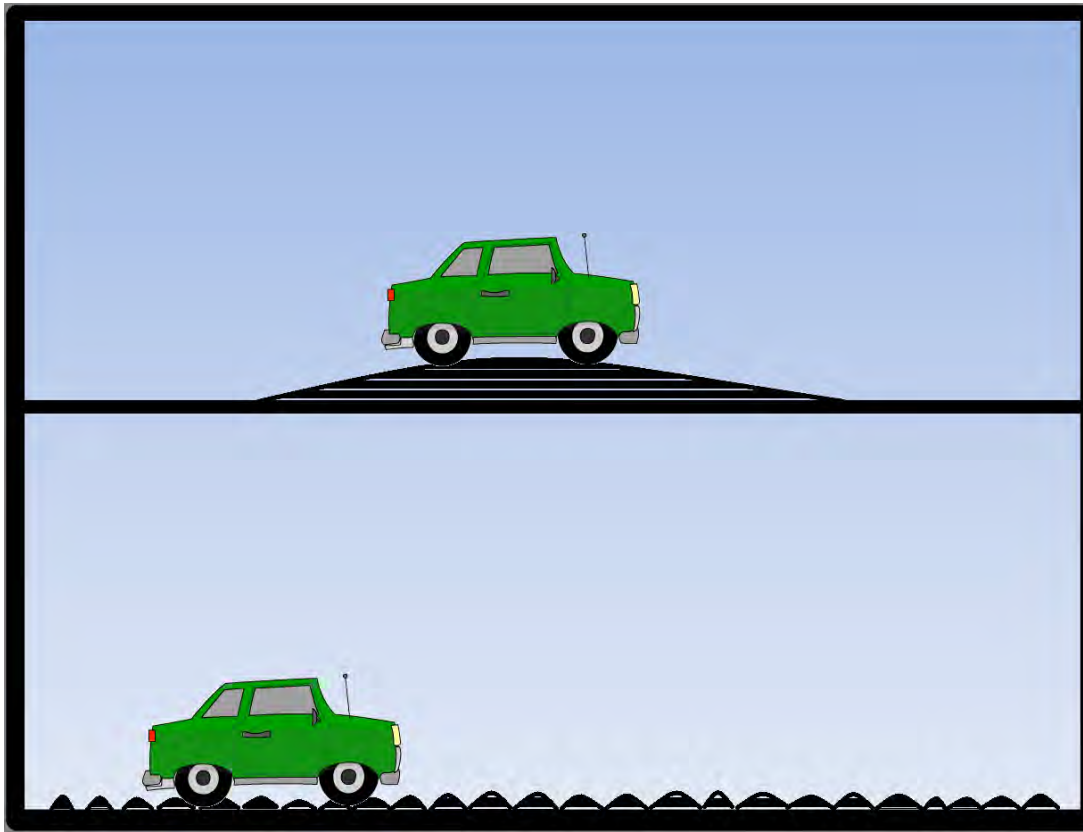
Low Frequency Hump

High Frequency Bumps

Low frequency heave, pitch, balance

- **Find low frequency hump**
  - ✓To make car move at Sprung Mass Resonance
- **Set dampers to full soft front and rear**
- **Drive over hump at increasing speed until car bounces**
  - ✓Observe visually
  - ✓Analyze data
- **Adjust damping to balance and damp**
  - ✓Fix pitch, then heave
  - ✓May have to adjust spring rates

In phase, underdamped

Steering

Throttle

Left Damper

Right Damper

Overdamped

Steering

Throttle

Left Damper

Right Damper
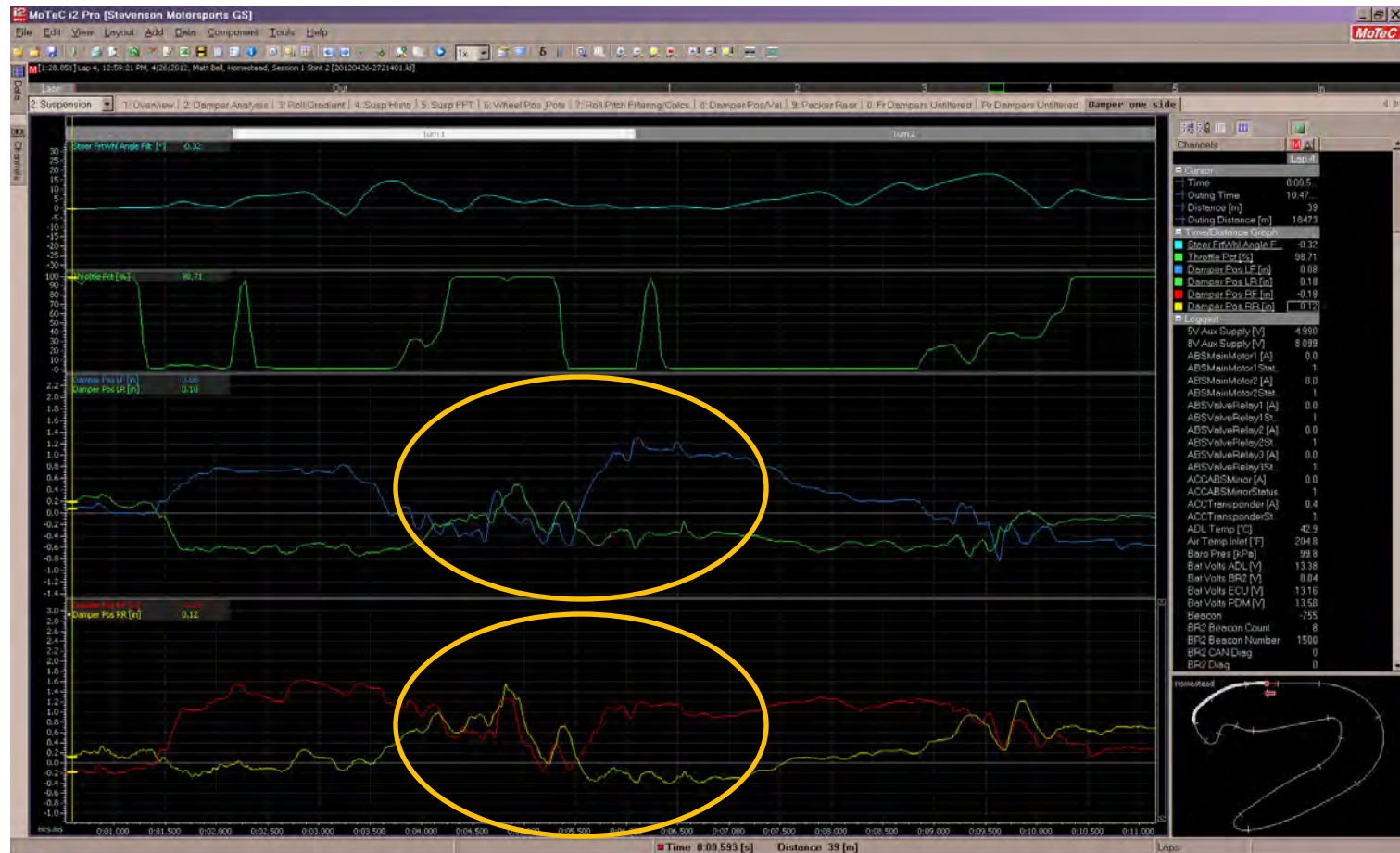
Shock Travel

Shock is topping out!

Rear Shocks

Steering

Throttle Brake

Understeer

Vehicle Input
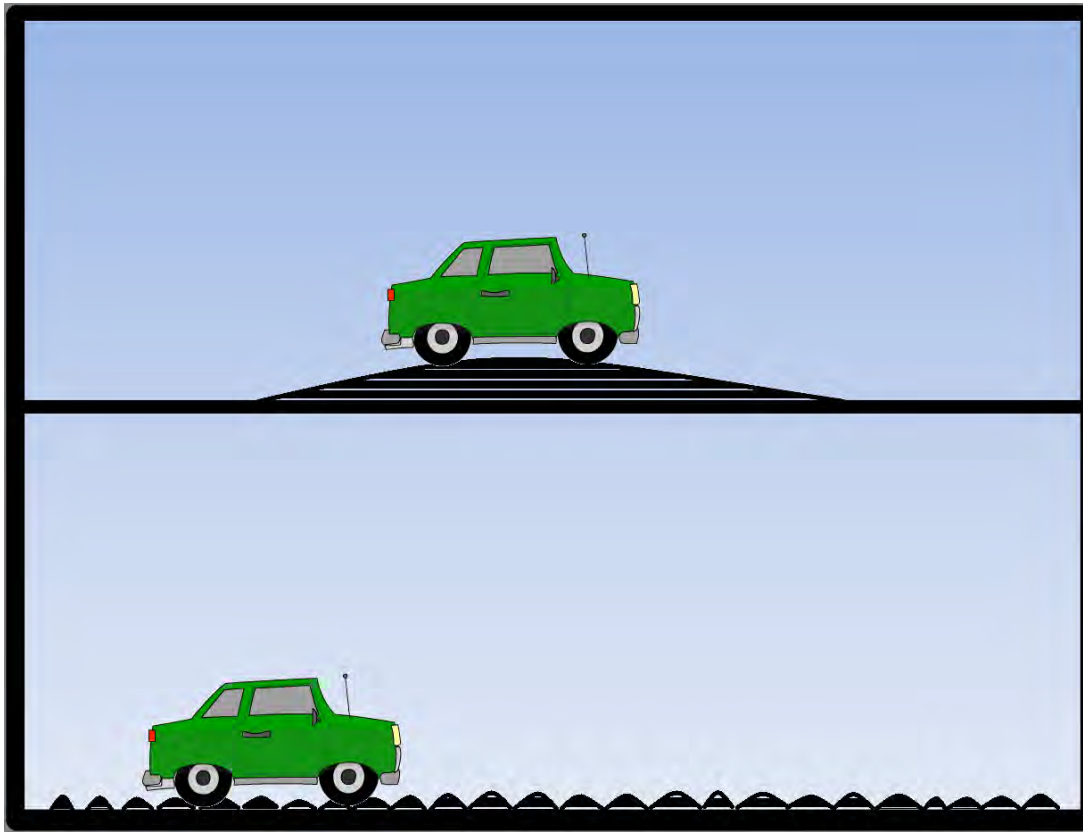
Low Frequency Hump

High Frequency Bumps

High frequency control

- **Find high frequency bumps**
  - ✓To make wheels resonate or bounce
- **Set dampers to low frequency settings**
- **Drive over bumps at increasing speed**
- **Do the tires bounce or go into resonance? Lose traction?**
  - ✓Observe visually
  - ✓Analyze data
- **Adjust damping**
  - ✓More AND less compression
  - ✓More AND less rebound

Damper Velocity Histogram
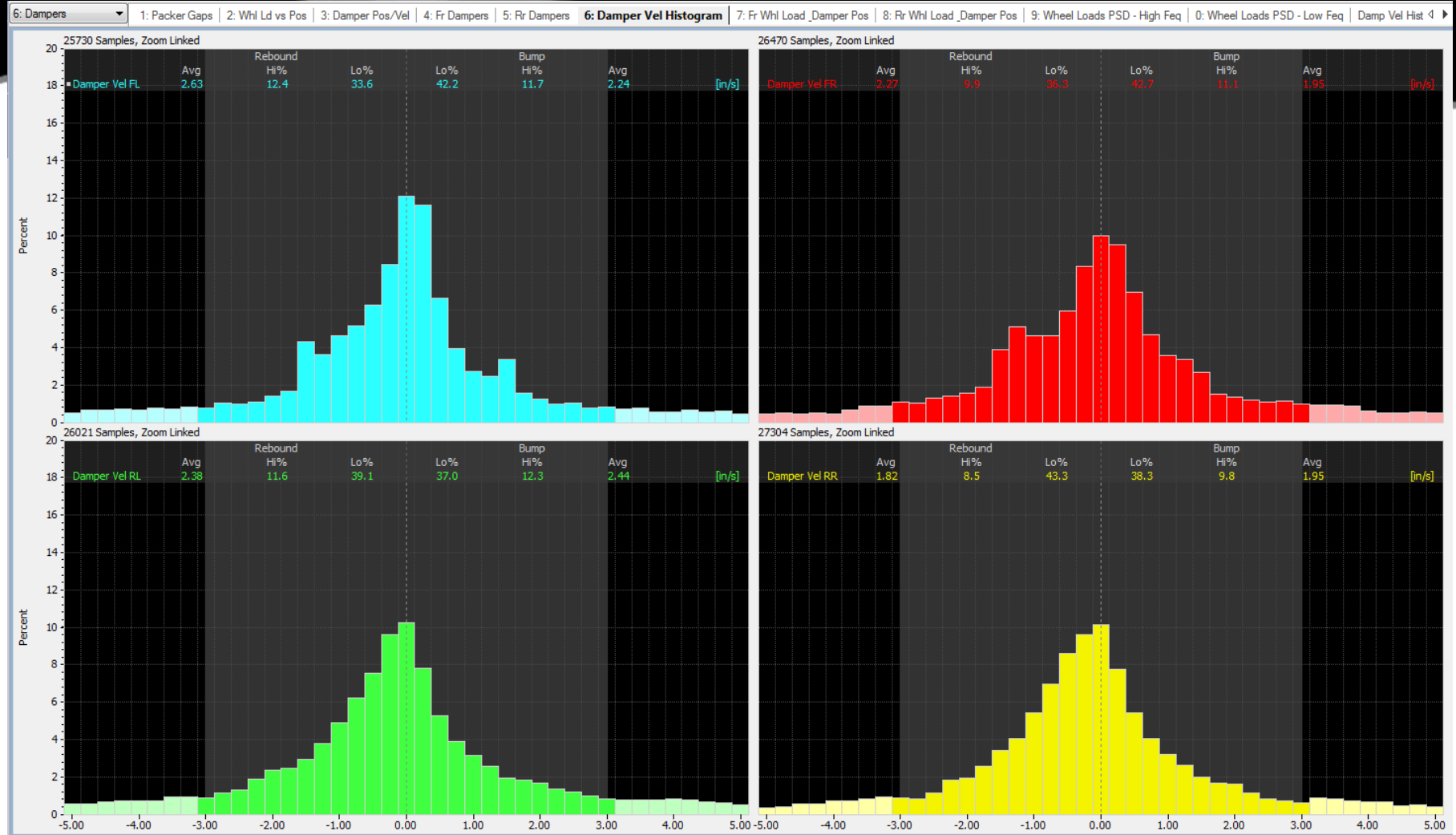
Damper Velocity Histogram
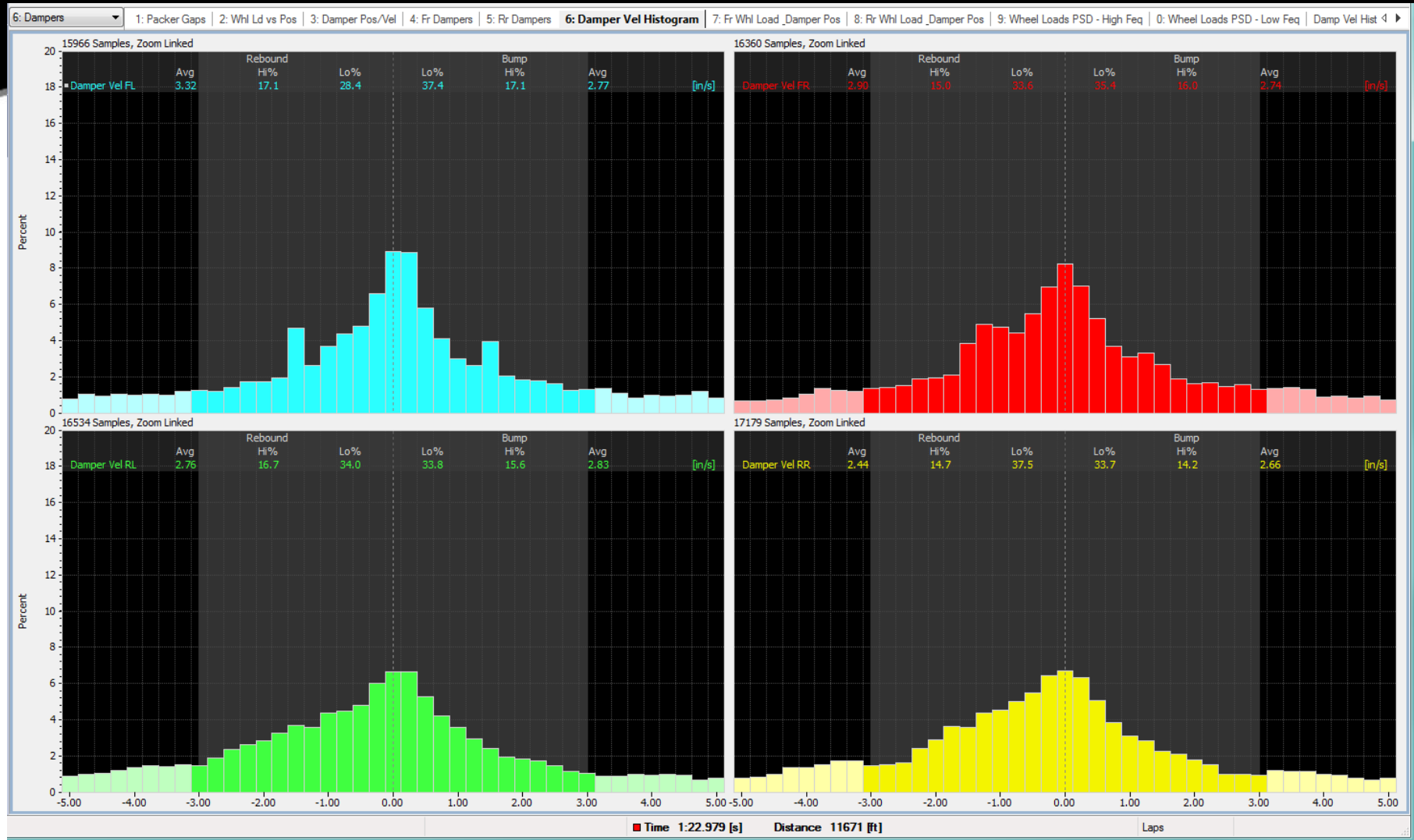
Basic Handling

Start Simple!!!

- **Simple course**
  - Oval
- **Does it brake in a straight line?**
- **Does it drive in a straight line?**
- **Does it shift properly?**
- **Any bottoming?**
- **Basic handling**
  - Braking, Entry, Exit

Basic Handling

Exit

Entry

Braking

Copyright Kaz Technologies 2012
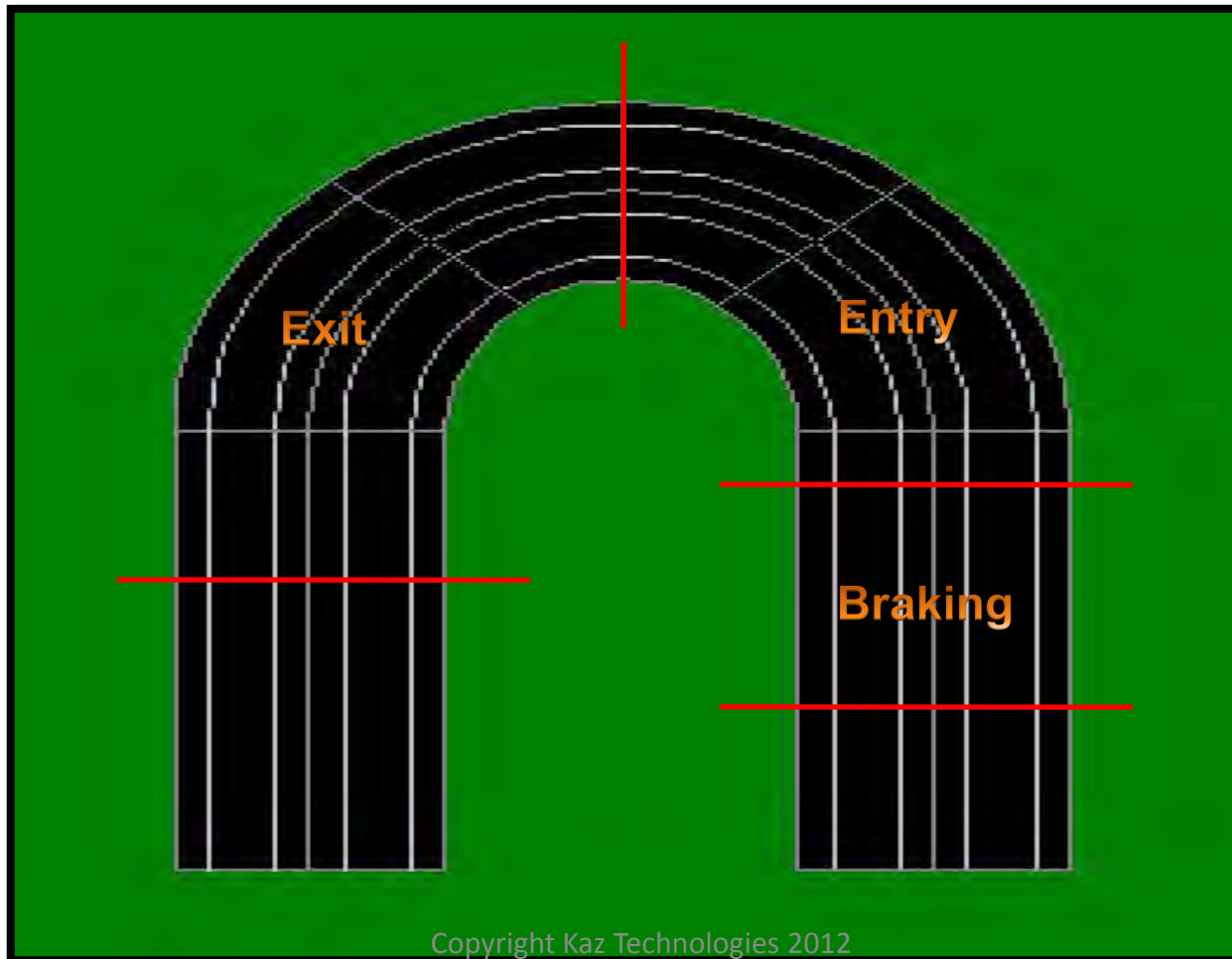
Basic Handling

- **Driver Questions**
  - **Braking**
    - ✓Stable? Yes, No
  - **Entry**
    - ✓Neutral, Understeer or Oversteer?
  - **Exit**
    - ✓Neutral, Understeer or Oversteer?

- **Look at vehicle response in data analysis**

Basic Handling

- **Start with the basics**
  - **Springs and swaybars**
  - **Aero**

- **Move to suspension adjustments**
  - **Camber, caster, toe**

- **Fine tune transitions with dampers**

Basic Handling

Exit

Entry

Braking

Copyright Kaz Technologies 2012
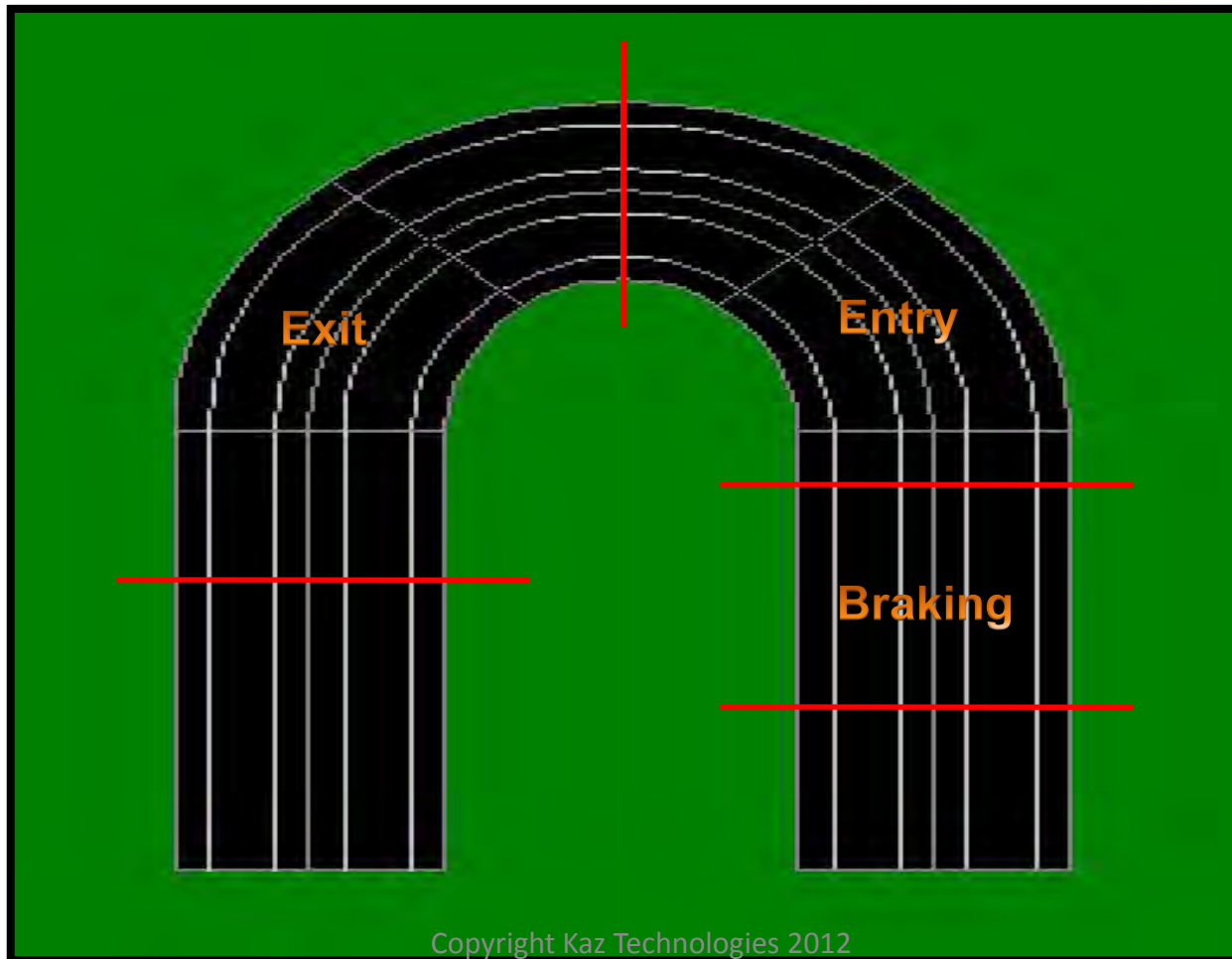
Handling

- **Braking**
  - **Car pulls to one side**
    - ✓ Bleed brakes
    - ✓ Toes even side to side?
  - **Rear instability**
    - ✓ Rear bumpsteer
    - ✓ Rear toe
      - ➢ More rear toe for increased stability
  - **Front instability**
    - ✓ Front bumpsteer
    - ✓ Front toe
      - ➢ Front toe-in for stability

Handling

- **Entry**
  - **Won't initiate turn**
    - ✓ Too much front spring?
    - ✓ Too much front compression?
    - ✓ Front toe out
  - **Understeer**
    - ✓ Less front spring
    - ✓ Softer front anti-roll bar
  - **Oversteer**
    - ✓ More rear toe
    - ✓ Softer rear anti-roll bar
    - ✓ Less rear spring

Handling

- **Exit**
  - **Oversteer**
    - ✓ Softer rear anti-roll bar
    - ✓ Less rear spring
    - ✓ Less rear damping
    - ✓ Rear camber
  - **Understeer**
    - ✓ Less front spring
    - ✓ Softer front anti-roll bar
    - ✓ More caster
    - ✓ More front camber

Vehicle Response Data
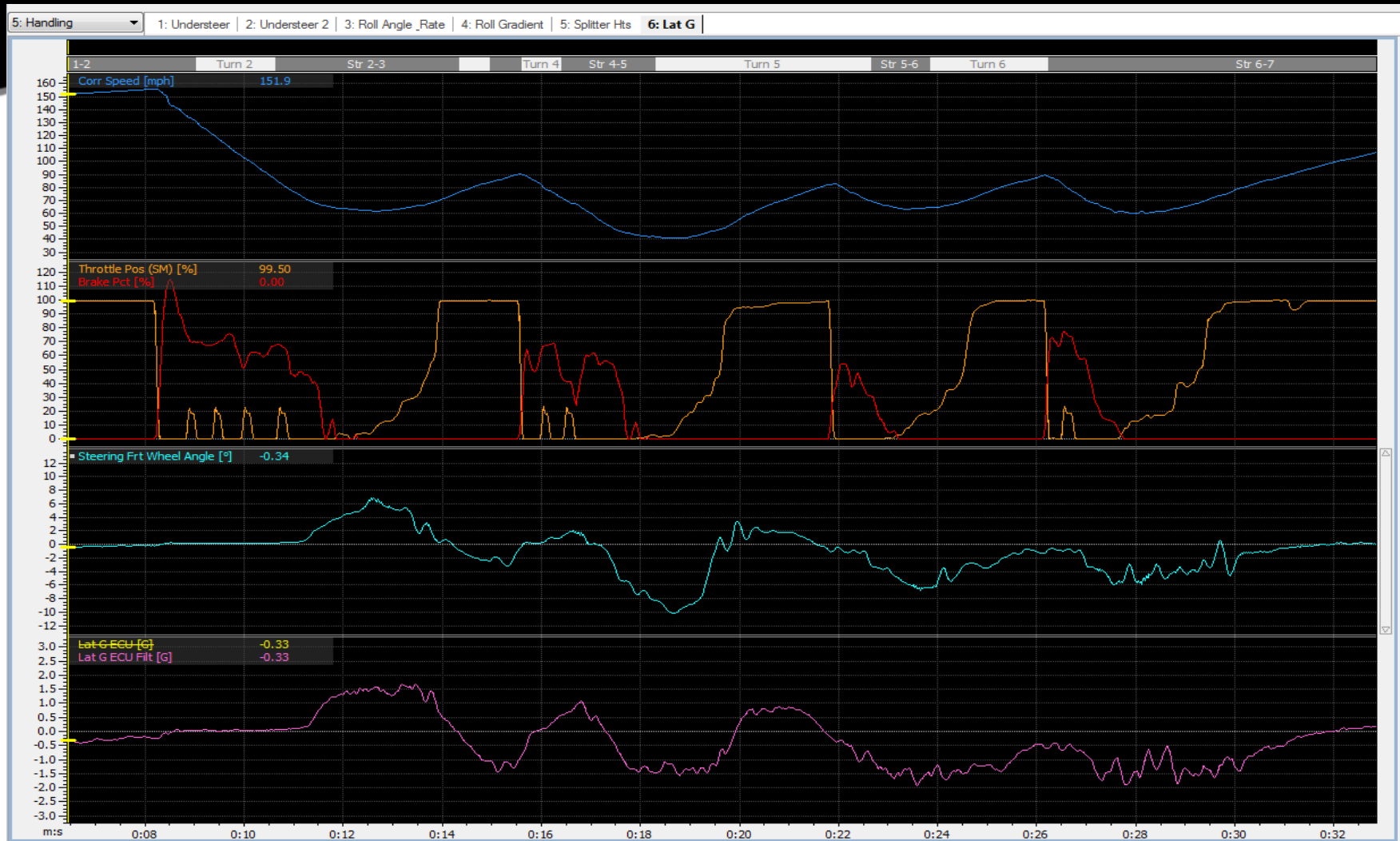
Vehicle Response Data

Advanced Handling

Copyright Kaz Technologies 2012

Advanced Handling

Accelerate and turn

Tight corner: brake & downshift

Chicane

Medium Speed Brake, no downshift

High speed: steady state

Copyright Kaz Technologies 2012
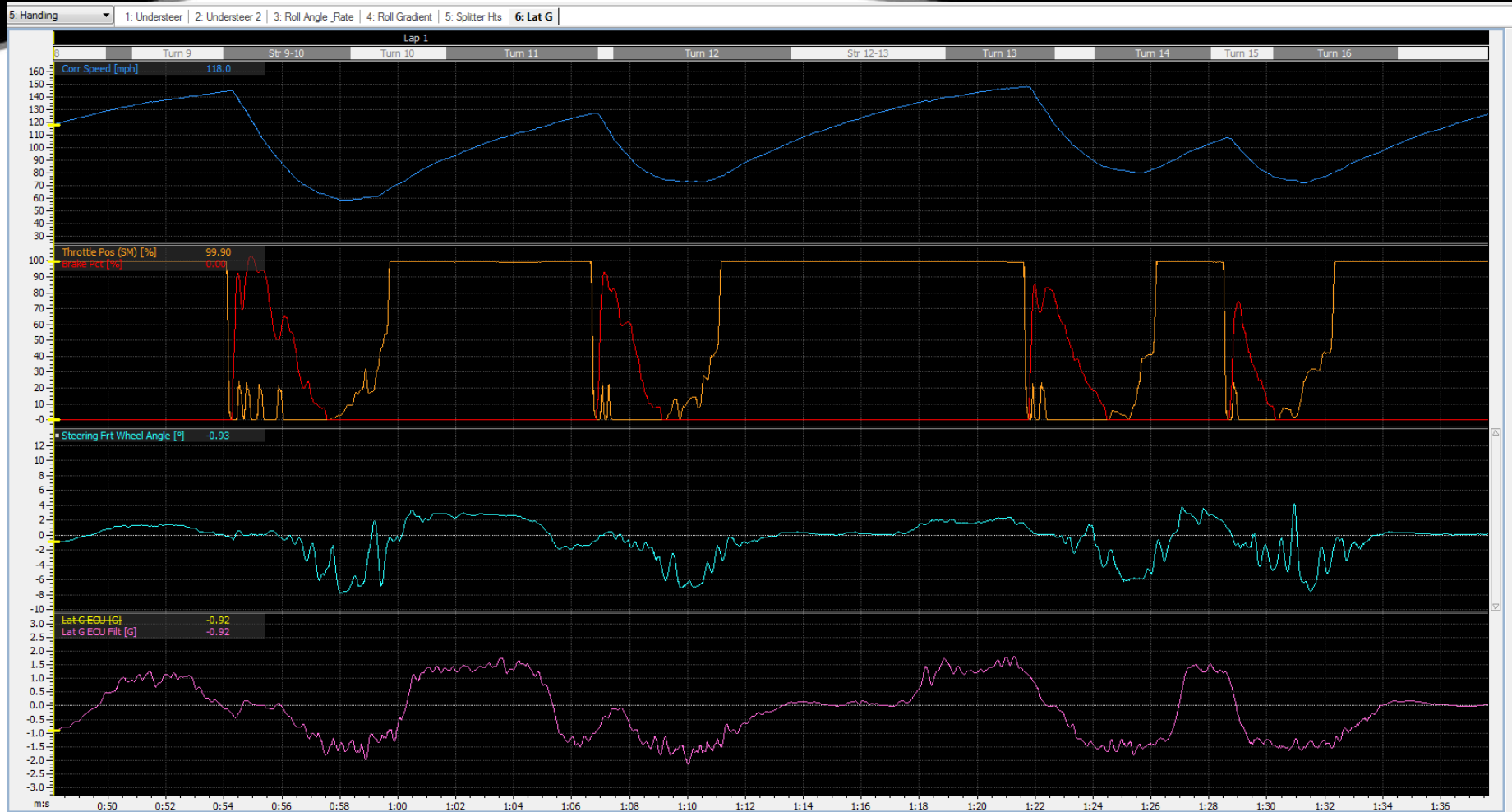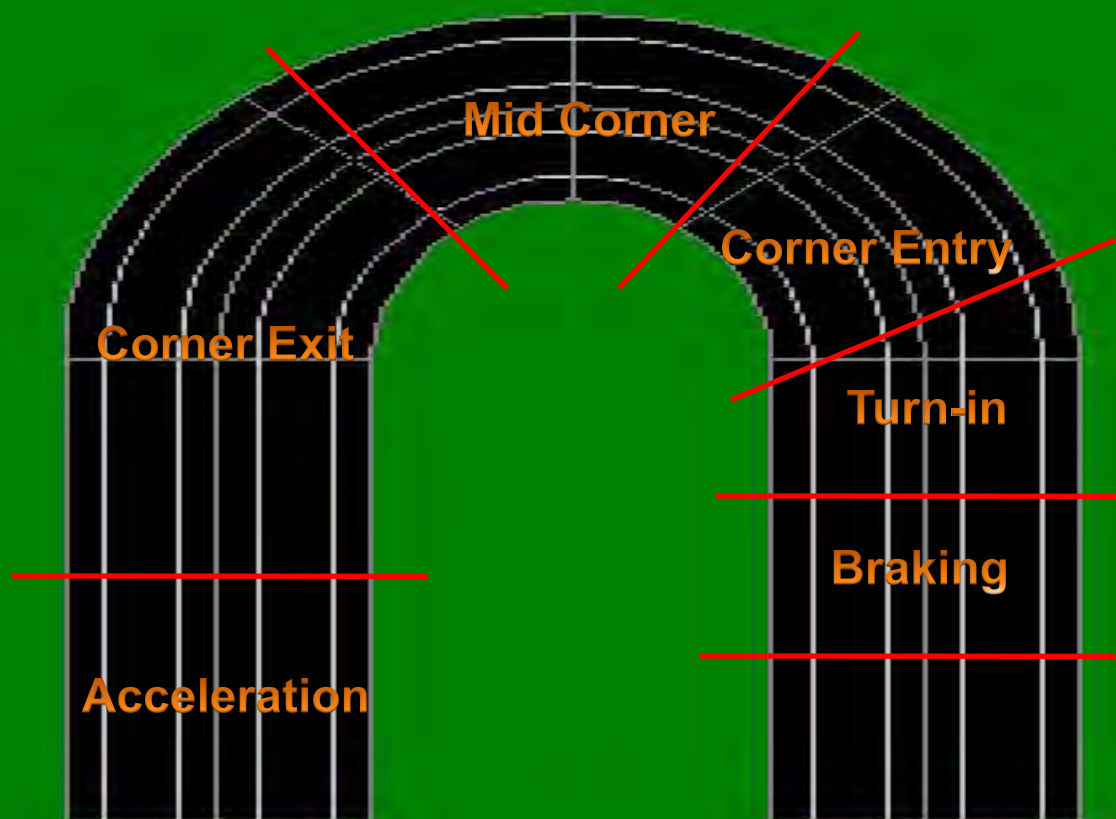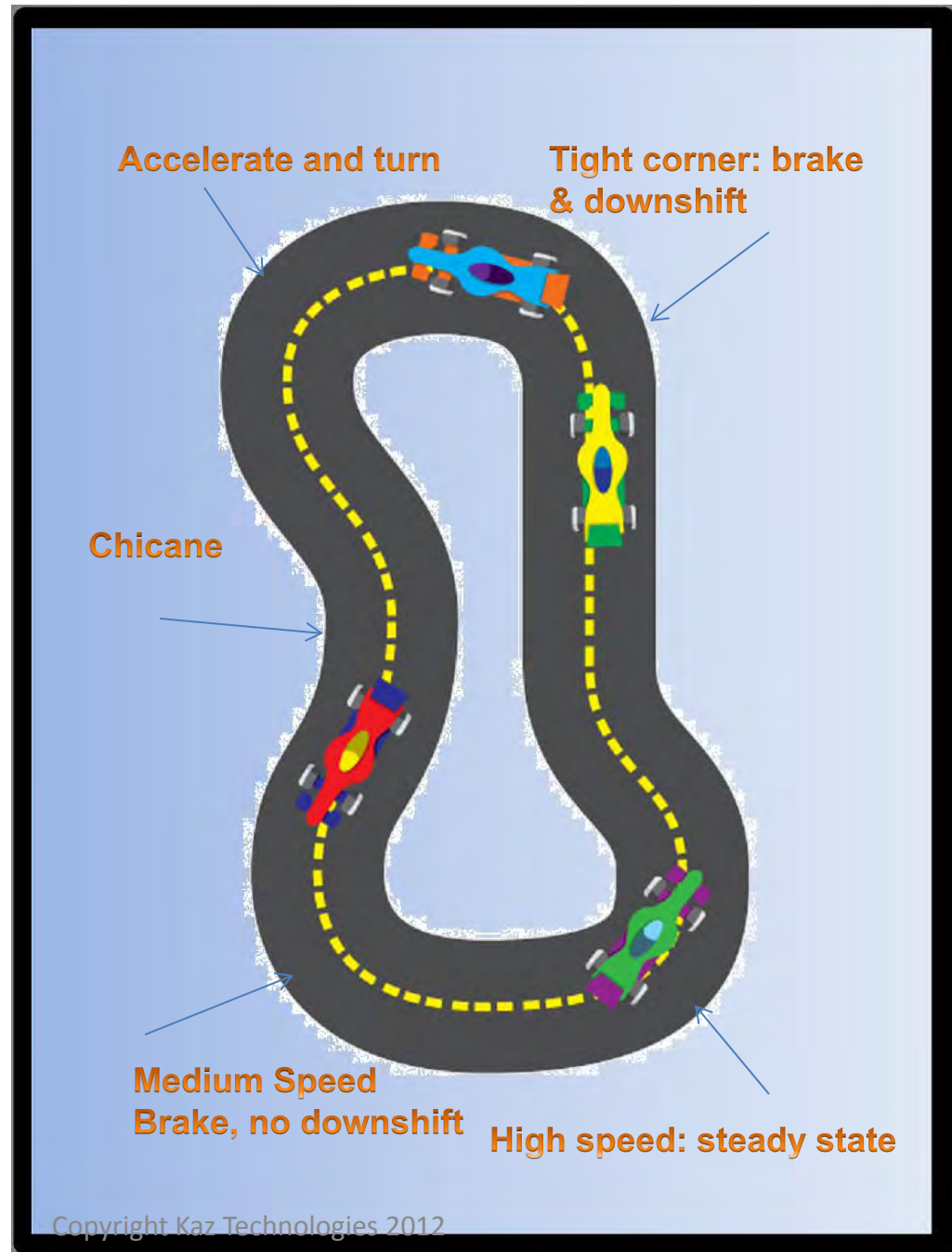
Damper Adjustments

➡️ **Turn the knobs one at a time**

➡️ **Turn them enough to make a difference**

➡️ **Determine what each knob does**

   Heave/pitch balance

   Braking

   Turn-in

   Mid-Corner

   Exit

➡️ **Turn the knobs again at the end of suspension tuning**

Test Summary

- **What went right?**

- **What went wrong?**

- **What worked?**

- **What didn't work?**

- **Issues**

- **Items for next test or event**

- **Final setup sheet**

Event Summary

Dates 1/6-8/13   Track Sebring Jan Test   Event Sebring Jan Test

Drivers Dominik Farnbacher, Jonathan Bomorito, Ben Keeting

Test Summary
To Be Done

Summary of Items tested
-Lower spring rates - Started 700/800, ended 600/600
-Softer FARB - Started 1.500, ended 1.38
-Penske adjustments
 -Rear HSC, Front LSR & LSC
-Lower rear ride ht/less rake
-Dynamic shocks
 -As Received adjustments
 -Front rebound P_IDJ
-Michelin soft compound
-JRI shocks
-Rear brake Frisbees

What Worked
-Lower spring rates
 -More grip, better on bumps
-Softer FARB
 -More front grip, better on bumps
-Penske shocks
 -Rear HSC, Front LSR & LSC
  -Less oscillation, positive driver comments
-Lower rear ride ht/less rake
 -Rear more stable, but more U/S
-Dynamic shocks (as received)
 -Instant lap time improvement (1.2 sec)
 -Better motion balance, less pitch
 -Softer Compression blow off - Better for impacts & Grip
 -Softer Front HSC - Better for impacts
-Dynamic shocks - Front Rebound P_IDJ
 -Less motion in front over bumps
-Michelin soft compound
 -Fastest times of test
 -Good lap times through 13 laps
-JRI shocks (Fr RadLin, Rr Inc Flow)
 -Times equal to Dynamics
 -Drivers like them better
 -Car motions as good as Dynamics

What did not work
-More rake
-Dynamic shocks
 '-More LSR
-Penske shocks
 -Less rear HSC - pitch was worse
 -Rear rebound - More helped pitch, but less stable
 -Rear rebound - less made pitch worse
-Dynamic shocks
 -Stiffer Front LSR - more understeer
-Michelin soft compound
 -Fronts started to give up after 6 laps
 -Rears started to give up after 9 laps
 -At 13 laps rears were really bad
-JRI shocks (Fr RadLin, Rr Inc Flow)
 -Can't run zero spring preload

#93 Car Issues
Location of rake Bias adjustment knob for Jonathan (he can't reach it!)
Steering column tilt heims have play in them

Other Issues
Need the ability for Chris to push data to Matt and I on timing stand

#93 Car - Things to consider for next time at Sebring
More front weight percentage
Less front anti-dive (Help lock-up sensitivity??)
Wing from 11 to 10 degrees
Gears: 4th shorter, maybe 3rd shorter

Questions!!

Kaz is here for you!

Questions?

FSAE_Shock@kaztechnologies.com

Topics to Discuss?

http://www.facebook.com/Kaz.Technologies

Start a discussion!

Thanks!

@KazTechnologies

WWW.KAZTECHNOLOGIES.COM

References

Books by Carroll Smith
- ✓ Engineer In Your Pocket
- ✓ Tune to Win
- ✓ Drive to Win
- ✓ Prepare to Win
- ✓ Engineer to Win
- ✓ Nuts, Bolts, Fasteners & Plumbing Handbook

Other Books
- ✓ Race Car Vehicle Dynamics
  William F. Milliken and Douglas L. Milliken
- ✓ Fundamentals of Vehicle Dynamics
  Thomas D. Gillespie
- ✓ Shock Absorber Handbook
  John C. Dixon