Damping Calculations

The Proper Damping for my Vehicle

Presented to Formula SAE

By Jim Kasprzak

KAZ TECHNOLOGIES

May 13, 2011

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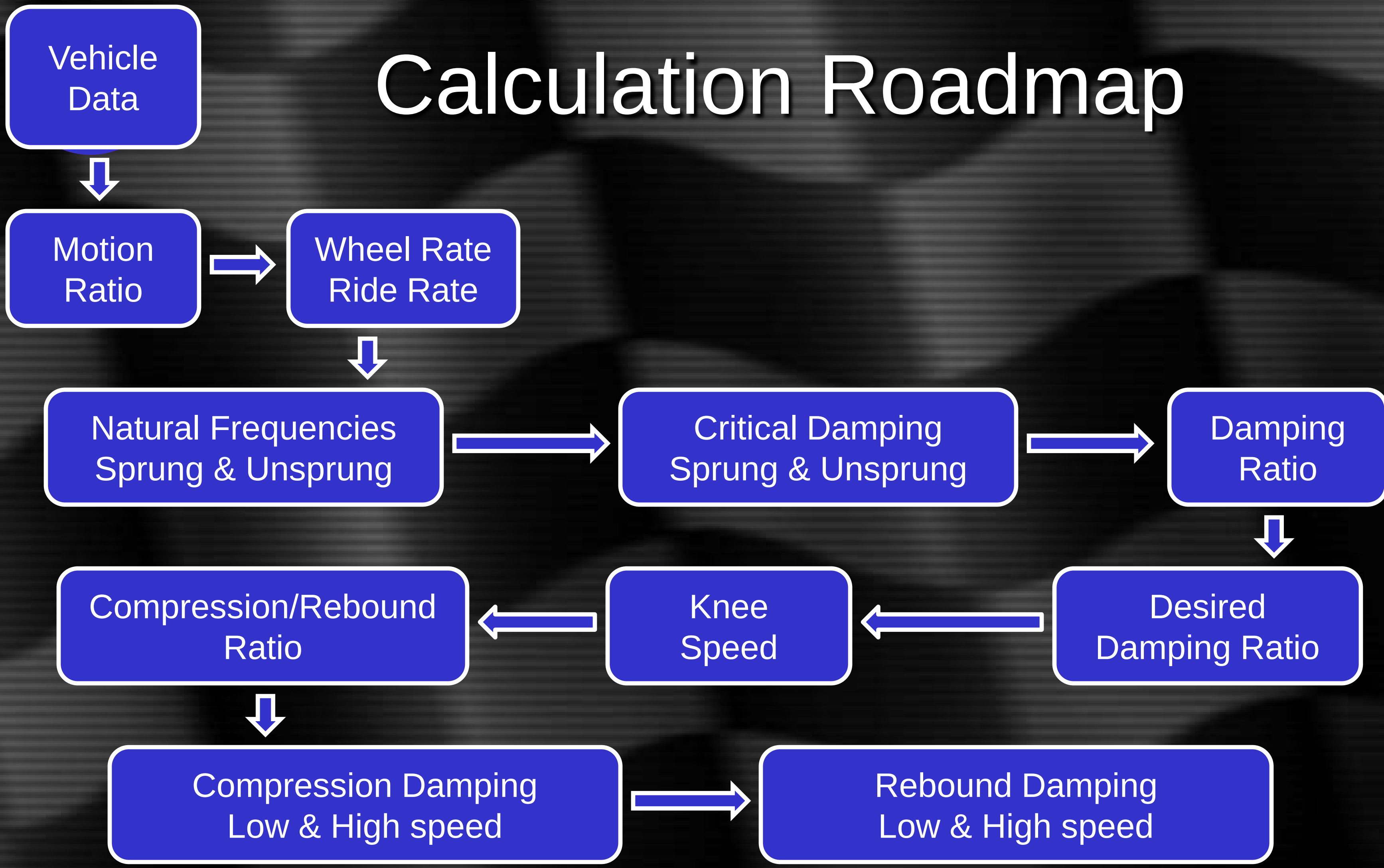
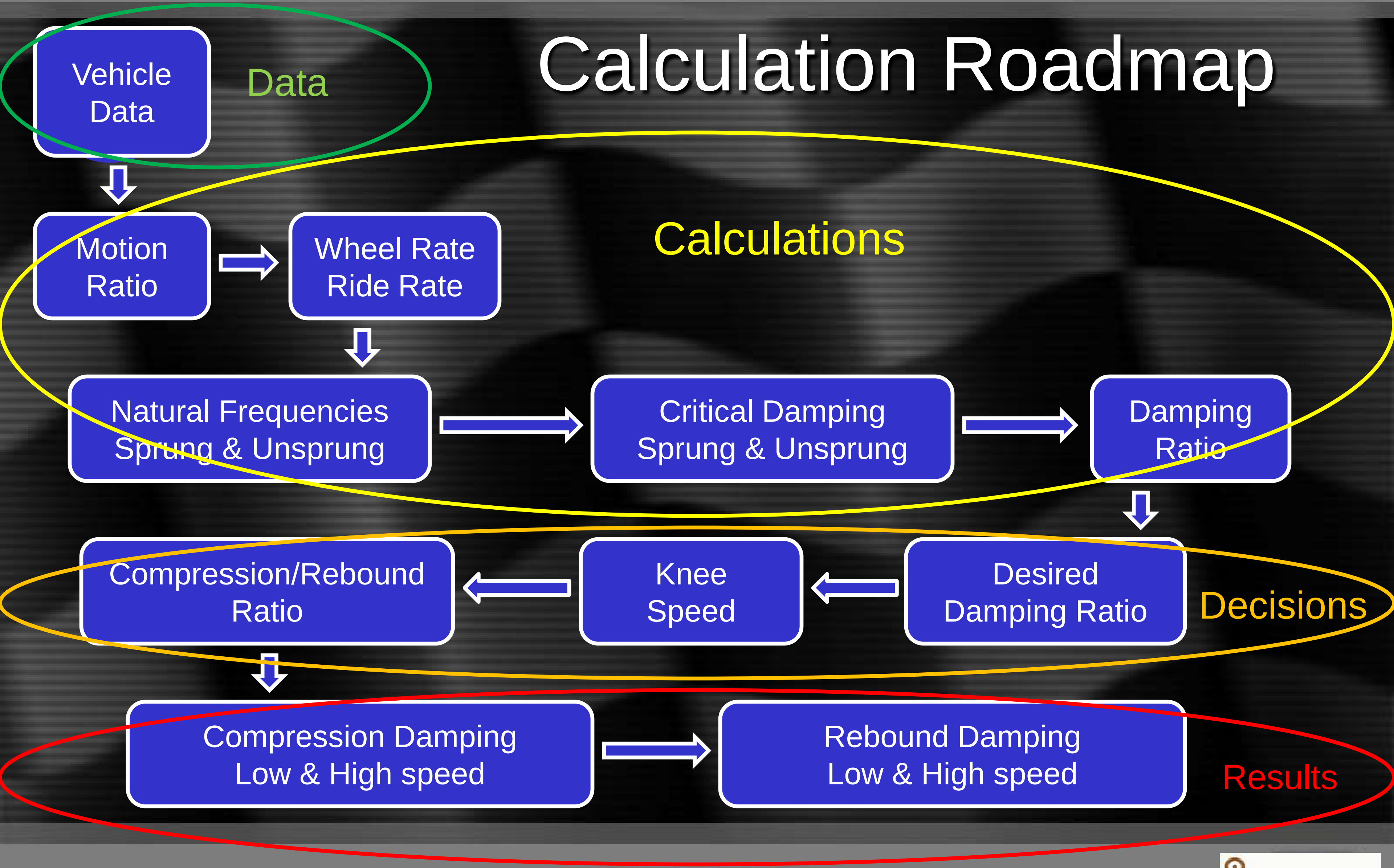
PLEASE ask questions

at any time

Calculation Roadmap



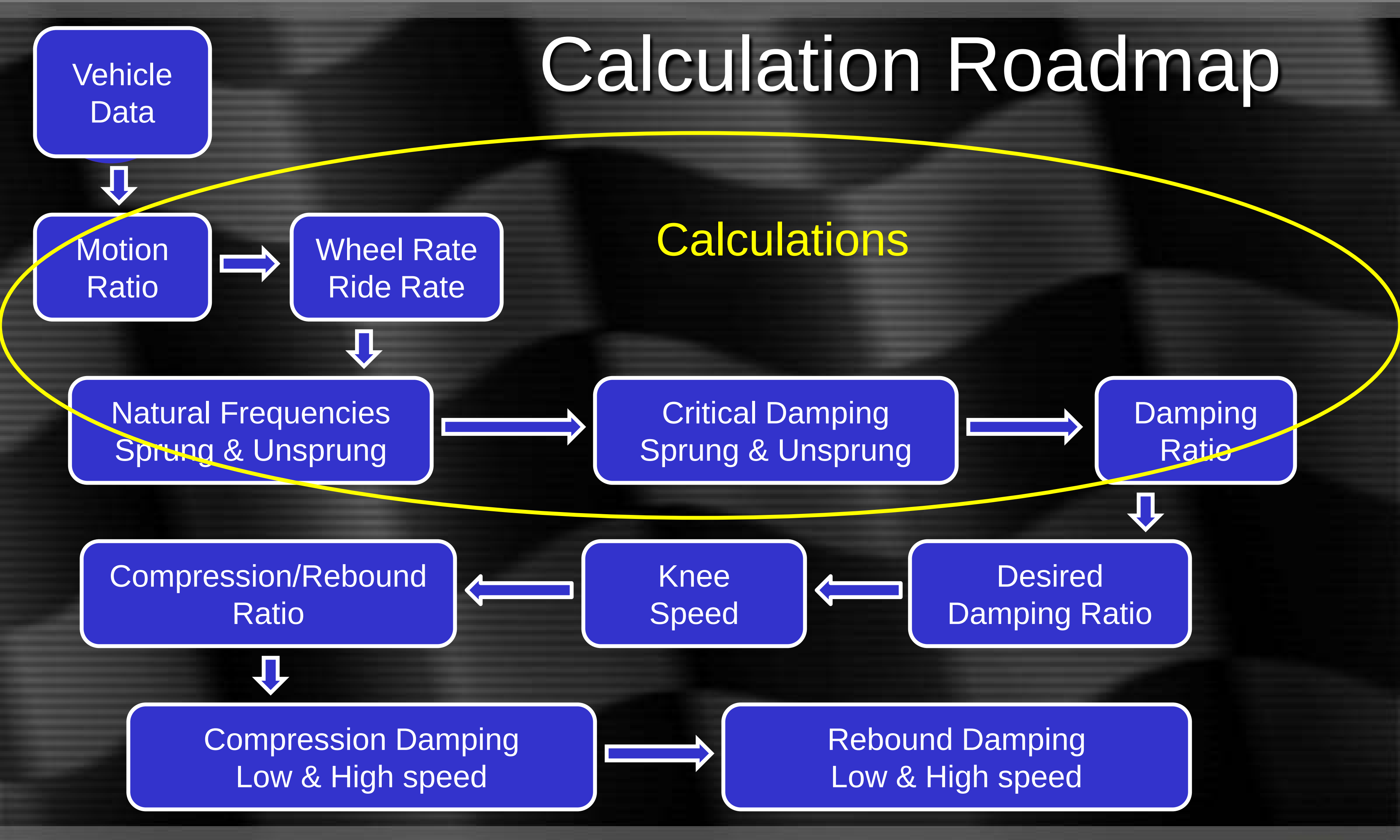
Calculation Roadmap



Calculation Roadmap

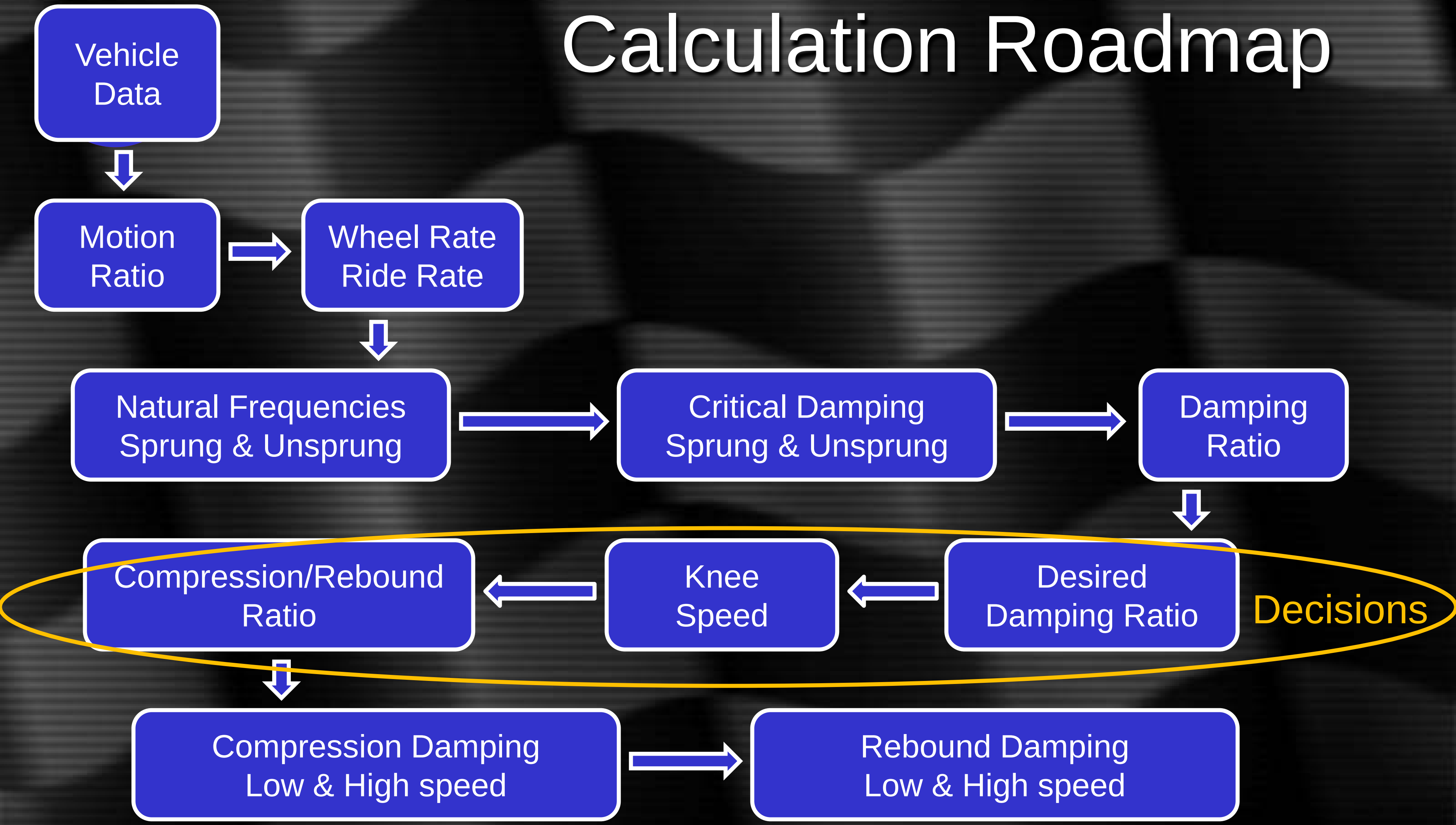
Data

- Vehicle Data
- Motion Ratio
- Wheel Rate / Ride Rate
- Natural Frequencies Sprung & Unsprung
- Critical Damping Sprung & Unsprung
- Damping Ratio
- Desired Damping Ratio
- Knee Speed
- Compression/Rebound Ratio
- Compression Damping Low & High speed
- Rebound Damping Low & High speed



Calculation Roadmap
Vehicle Data
Motion Ratio
Wheel Rate Ride Rate
Calculations
Natural Frequencies Sprung & Unsprung
Critical Damping Sprung & Unsprung
Damping Ratio
Compression/Rebound Ratio
Knee Speed
Desired Damping Ratio
Compression Damping Low & High speed
Rebound Damping Low & High speed

Calculation Roadmap



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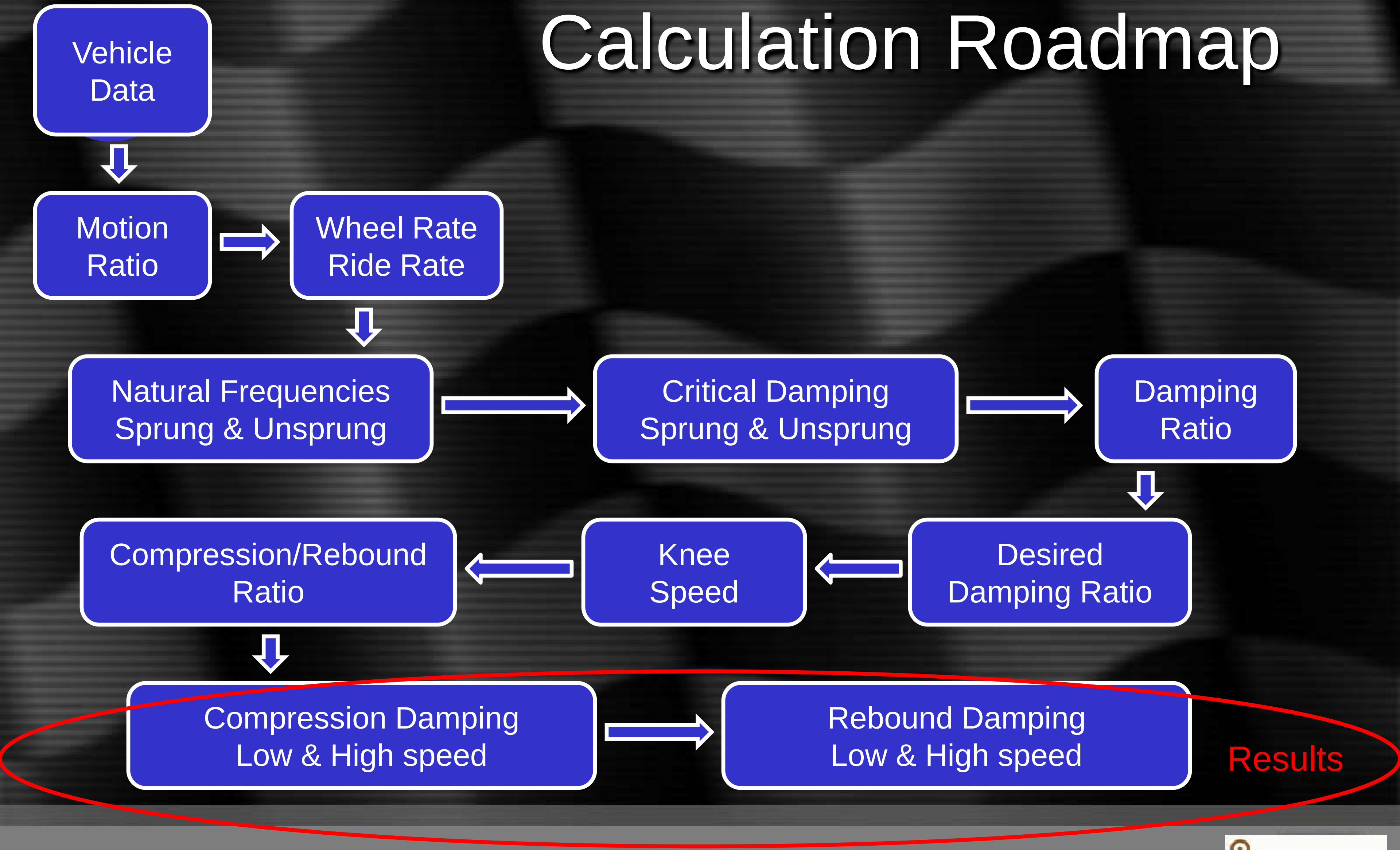

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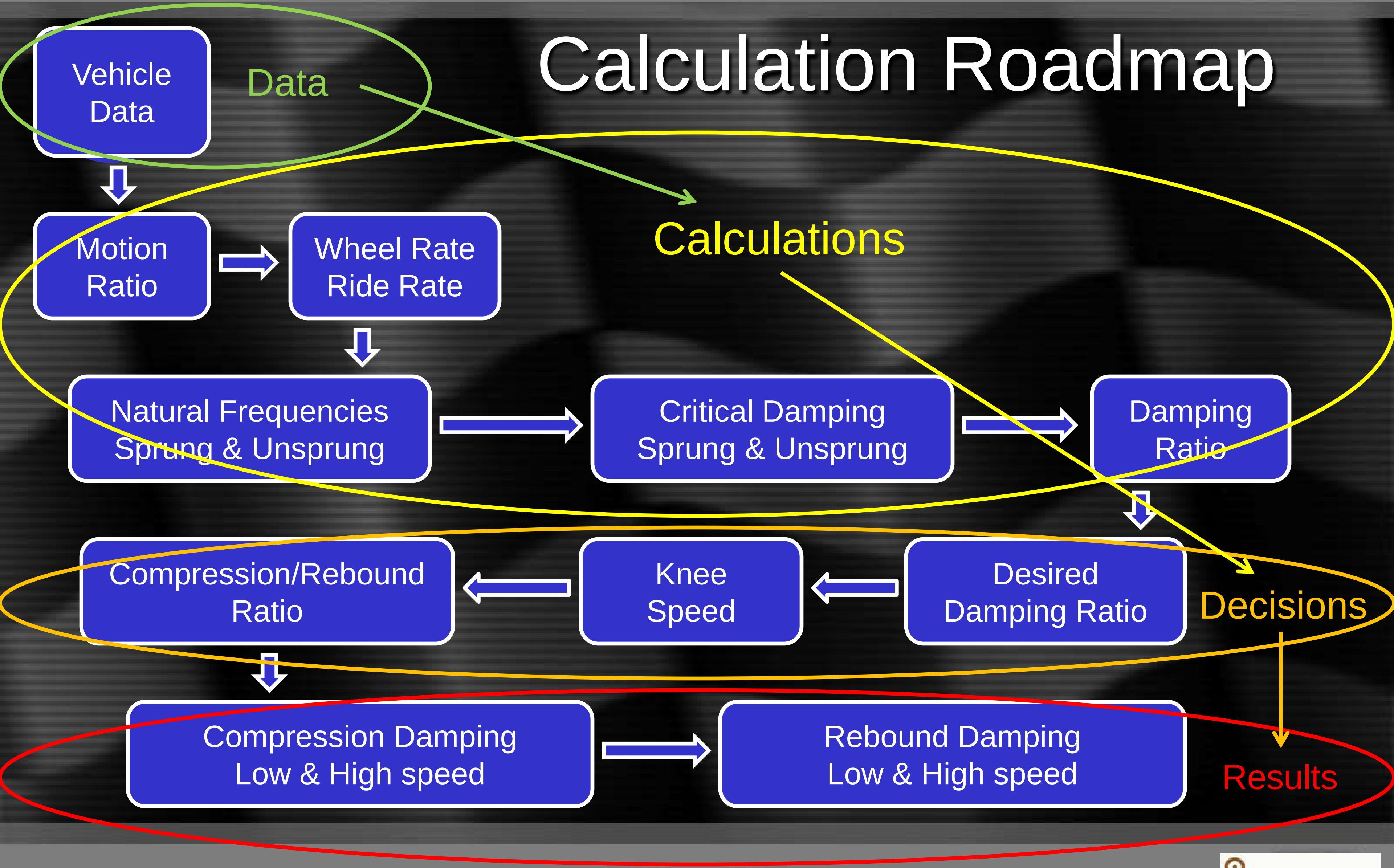


KAZ Technologies

- KAZ TECHNOLOGIES started in 1995
- Staff of 6 Engineers
  - Over 85 years of combined racing & automotive engineering experience
- Extensive vehicle suspension, ride and handling experience
  - Damper design, development, testing and manufacturing
  - All types of springs, stabilizer bars, oil seals, shock absorbers and struts
  - Ride & handling on standard suspension and advanced technologies
  - NVH, tire testing, vehicle stability systems, race chassis development
  - 7-Post and 4-Post test development and testing

Experience

Racing experience includes:

- Race driving
- Race engineering
- Chassis/Suspension development
- Data acquisition and analysis
- Suspension design, analysis & fabrication
- Shock absorber development
- 7-Post Testing

KAZ TECHNOLOGIES

- GM Racing
  - Resident 7-post and shock technical specialists
  - 7-post testing for GM Racing
  - 7-Post & damper testing tools
  - Race engineering
- Other
  - Race engineering
  - Damper design & development
  - Damper sales & service

Jim Kasprzak-Race Engineering

- 36 years racing experience
- Developed 7-Post testing for GM
- Expertise includes:
  - Race Engineering
  - 7-Post testing
  - Suspension engineering
  - Shock design, development & tuning
  - Vehicle tuning

Jim Kasprzak-Automotive

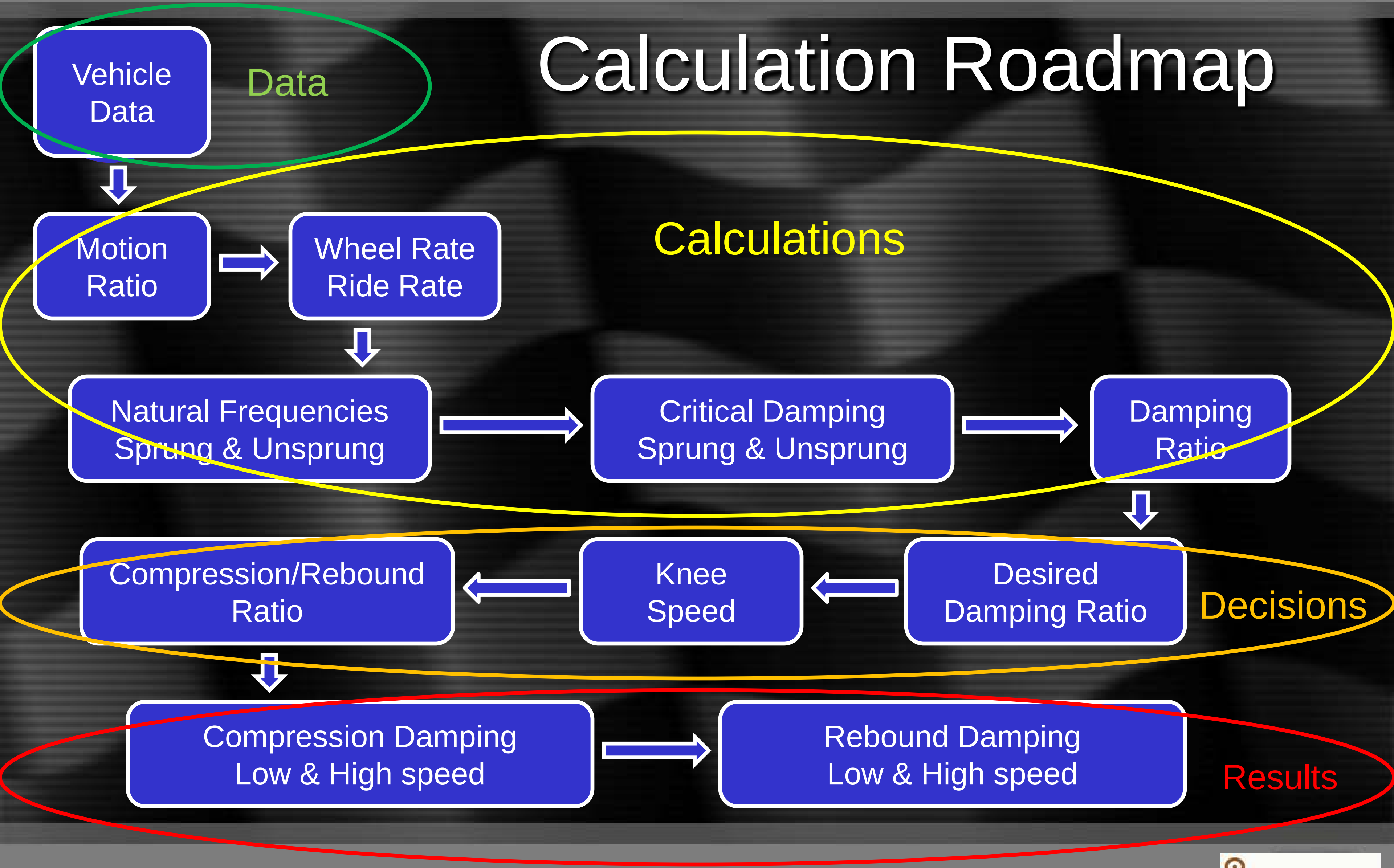
- 31 years automotive experience
- Arvin Ride Control
  - Director, Original Equipment Engineering
  - Director, New Product Development
- Monroe Auto Equipment
  - Chief Engineer, Electronic Suspensions
  - Manager, Suspension System Programs
- Two shock design patents

“Sometimes I think that I would have enjoyed racing more in the days of the friction shock. Since you couldn’t do anything much to them or with them, I would have spent a lot less time being confused.”

Carroll Smith

Tune to Win, 1978

Calculation Roadmap



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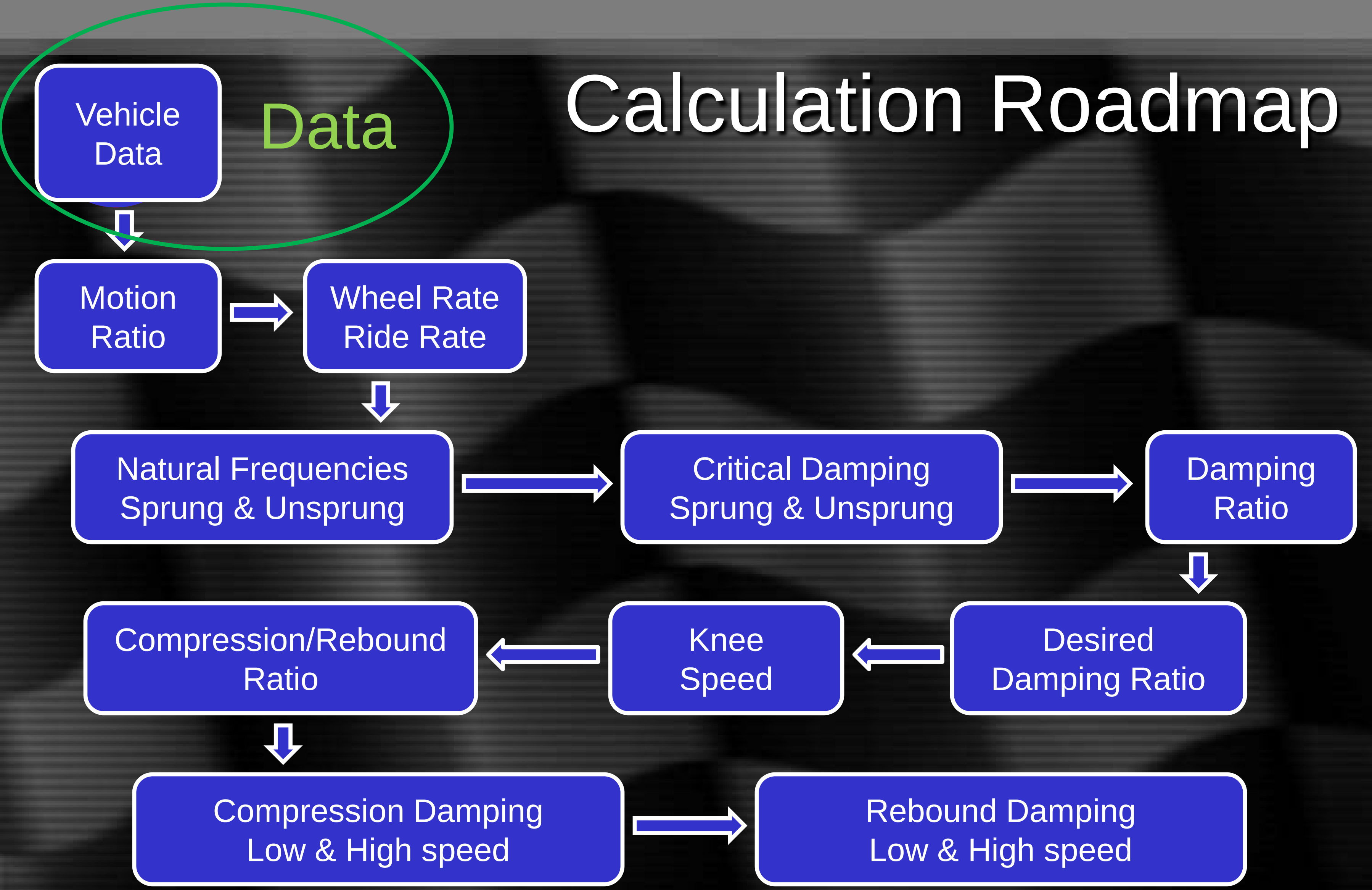

Vehicle Data

- Total Vehicle weight
- % Front vehicle weight
- Front & rear unsprung weight
- Front & rear shock/wheel motion ratios
- Tire radial stiffness
- Front & rear spring rates

Vehicle Data Definitions

Total Vehicle Weight

- Total vehicle weight ready to race with driver, fluids and ½ tank of fuel

% Front Vehicle Weight

- Percentage of vehicle's weight measured at the front wheels

Vehicle Data Definitions

Unsprung Weight

- The weight of those parts of the car which are not carried by the suspension system, but are supported directly by the tire and wheel assembly and considered to move with it.

CarDictionary.com

Vehicle Data Definitions

Motion Ratio

- The ratio of shock/spring travel to wheel travel

$$\textit{Spring Motion Ratio} = \frac{\textit{Spring Displacement}}{\textit{Wheel Displacement}}$$

$$\textit{Shock Motion Ratio} = \frac{\textit{Shock Displacement}}{\textit{Wheel Displacement}}$$

Vehicle Data Definitions

Tire Radial Stiffness

- Vertical spring rate of the tire
- Obtained from tire test data
- Tire pressure dependant
- Data available as member of the FSAE Tire Test Consortium

Vehicle Data Definitions

Spring Rate

- The ratio of spring load to deflection

$$Spring\ Rate = \frac{Spring\ Load}{Spring\ Deflection}$$

Vehicle Data

- Total Vehicle weight
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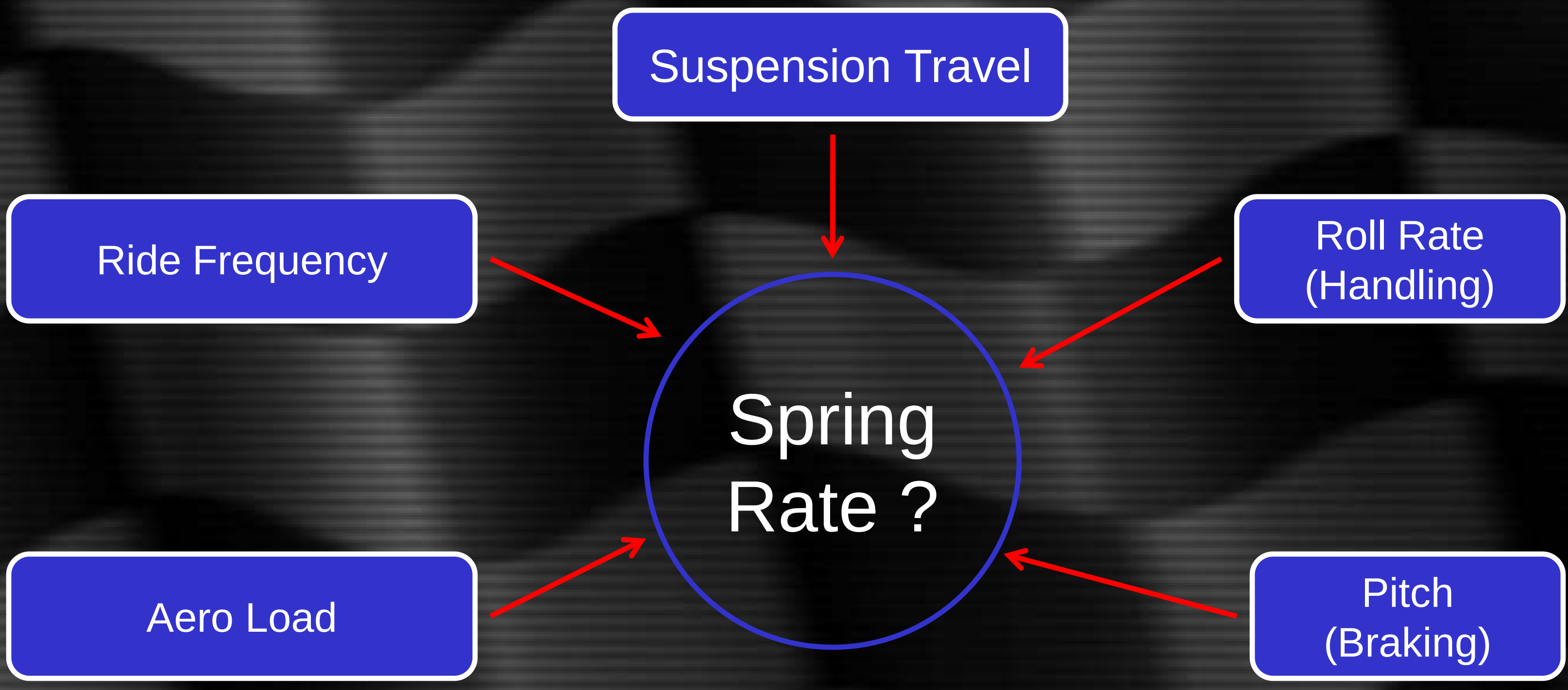
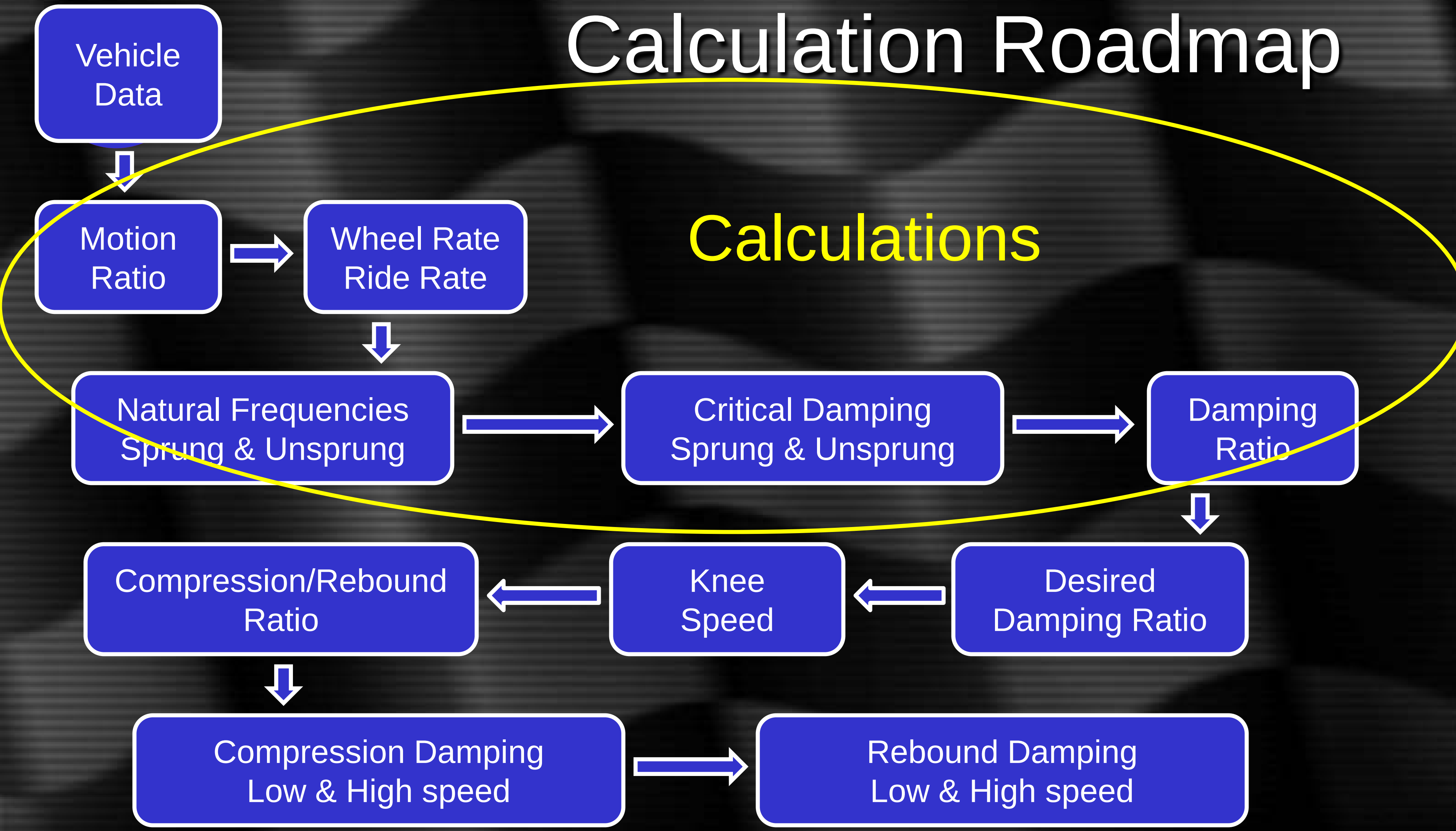
Spring Rates



Vehicle Data Units

- Total Vehicle weight (kilograms)
- % Front vehicle weight (percentage - %)
- Front & rear unsprung weight (kilograms)
- Front & rear shock/wheel motion ratios (unitless)
- Tire radial stiffness (Newton/millimeter)
- Front & rear spring rates (Newton/millimeter)

Calculation Roadmap



Motion Ratio

The ratio of spring travel to wheel travel

$$MR = \text{Motion Ratio} = \frac{\text{Spring Displacement}}{\text{Wheel Displacement}}$$

Wheel Rate

The spring rate at the wheel

$$Wheel\ Rate = K_W = K_S * MR^2$$

K_W = Wheel Rate (N/m)
K_S = Spring Rate (N/m)
MR = Motion Ratio (unitless)

Ride Rate

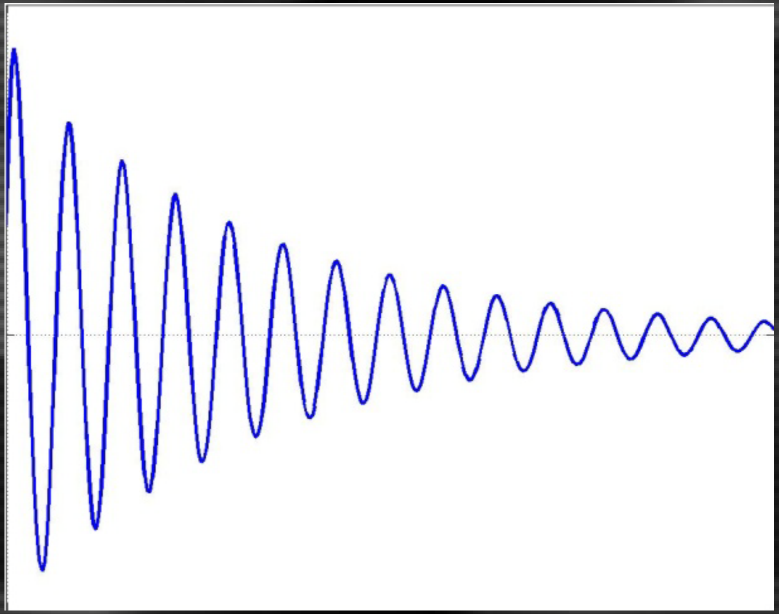
The effective stiffness of the suspension and tire springs in series

$$Ride\ Rate = K_R = \frac{K_W * K_T}{K_W + K_W}$$

K_R = *Ride Rate (N/m)*
K_W = *Wheel Rate (N/m)*
K_T = *Tire Spring Rate (N/m)*

Natural Frequency

The undamped resonant frequency of the system



Natural Frequency

The undamped resonant frequency of the system

$$Resonant\ Frequency = \omega_n = \frac{1}{2\pi}\sqrt{\frac{K_S}{M}}$$

$$\omega_n = Resonant\ Frequency\ (Hz)$$

K_S = Spring Rate (N/m)
M = Mass (kg)

Sprung Mass Natural Frequency

The undamped resonant frequency of the sprung mass

$$\textit{Sprung Mass Nat Freq} = \omega_n(s) = \frac{1}{2\pi}\sqrt{\frac{K_R}{W_S/g}}$$

$$\omega_n(s) = \textit{Sprung mass Natural Frequency (Hz)}$$

K_R = Ride Rate (N/m)
W_S = Sprung Weight (kg)
g= Acceleration due to Gravity (m/sec^2)

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Unsprung Mass Natural Frequency

The undamped resonant frequency of the unsprung mass

$$Unsprung\ Mass\ Nat\ Freq = \omega_n(us) = \frac{1}{2\pi}\sqrt{\frac{K_S + K_T}{W_{US}/g}}$$

$$\omega_n(us) = Unsprung\ mass\ Natural\ Frequency\ (Hz)$$

K_S = Spring Rate (N/m)
K_T =Tire Rate (N/m)
W_{US} = Unsprung Weight (kg)
g= Acceleration due to Gravity (m/sec^2)

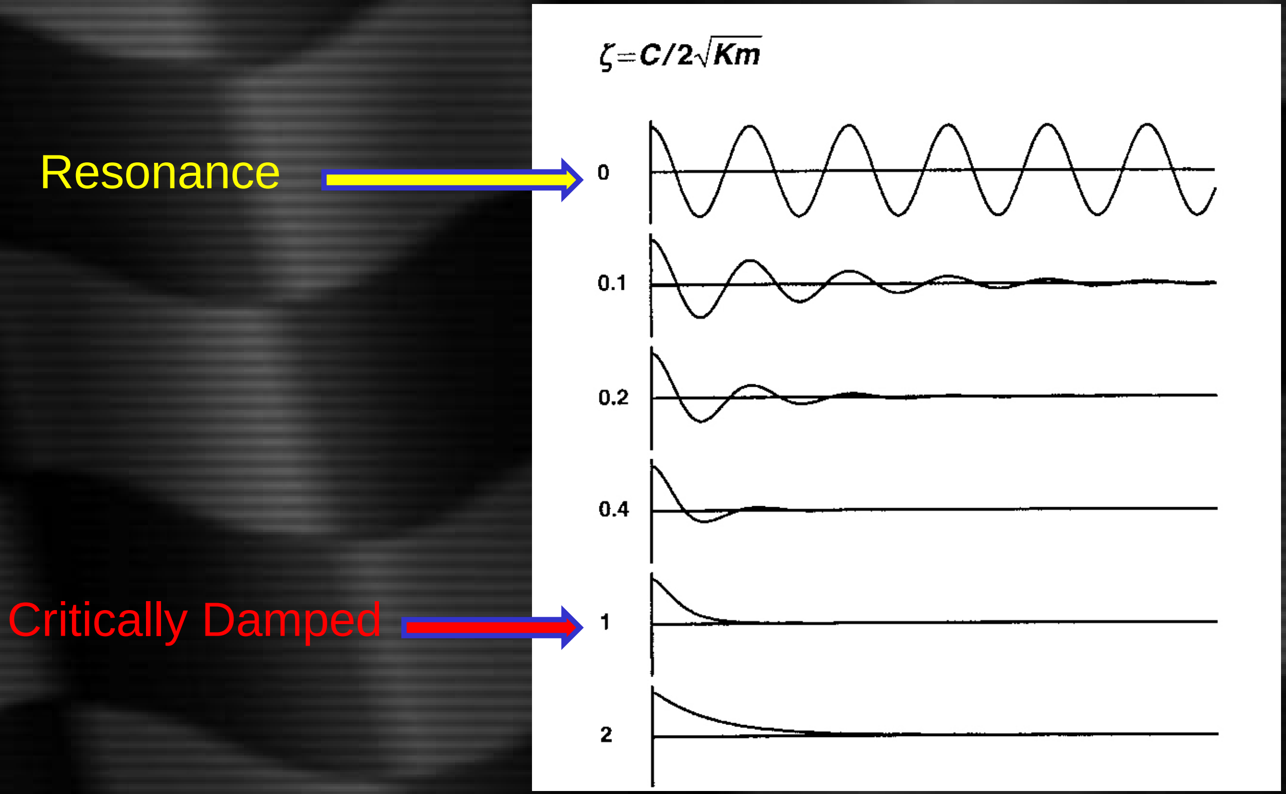
Critical Damping

The level of damping that allows the mass to return to steady state most quickly with no overshoot is *critical damping.*

$$C_{cr} = 2\sqrt{K_s * M}$$

C_{cr} = Critical Damping Coefficient (N-s/m)
K_S = System Spring Rate (N/m)
M = System Mass (kg)

Critical Damping



Sprung Mass Critical Damping

The critical damping coefficient for the sprung mass

$$C_{cr}(s) = 2\sqrt{K_R * W_S/g}$$

$C_{cr}(s)$ = Sprung mass critical damping coefficient (N-s/m)

K_R = Ride Rate (N/m)

W_S = Sprung Weight (kg)

g= Acceleration due to Gravity (m/sec^2)

Unsprung Mass Critical Damping

The critical damping coefficient for the unsprung mass

$$C_{cr}(us) = 2\sqrt{K_S + K_T * W_{US}/g}$$

$C_{cr}(us)$ = Unsprung mass critical damping coefficient (N-s/m)
K_S = Spring Rate (N/m)
K_T =Tire Rate (N/m)
W_{US} = Unsprung Weight (kg)
g= Acceleration due to Gravity (m/sec^2)

Damping Ratio

The relationship of the damping coefficient to the coefficient at critical damping. Think of it as a damping rate.

$$\varepsilon = \frac{C}{C_{cr}}$$

ξ = Damping Ratio (N-s/m)

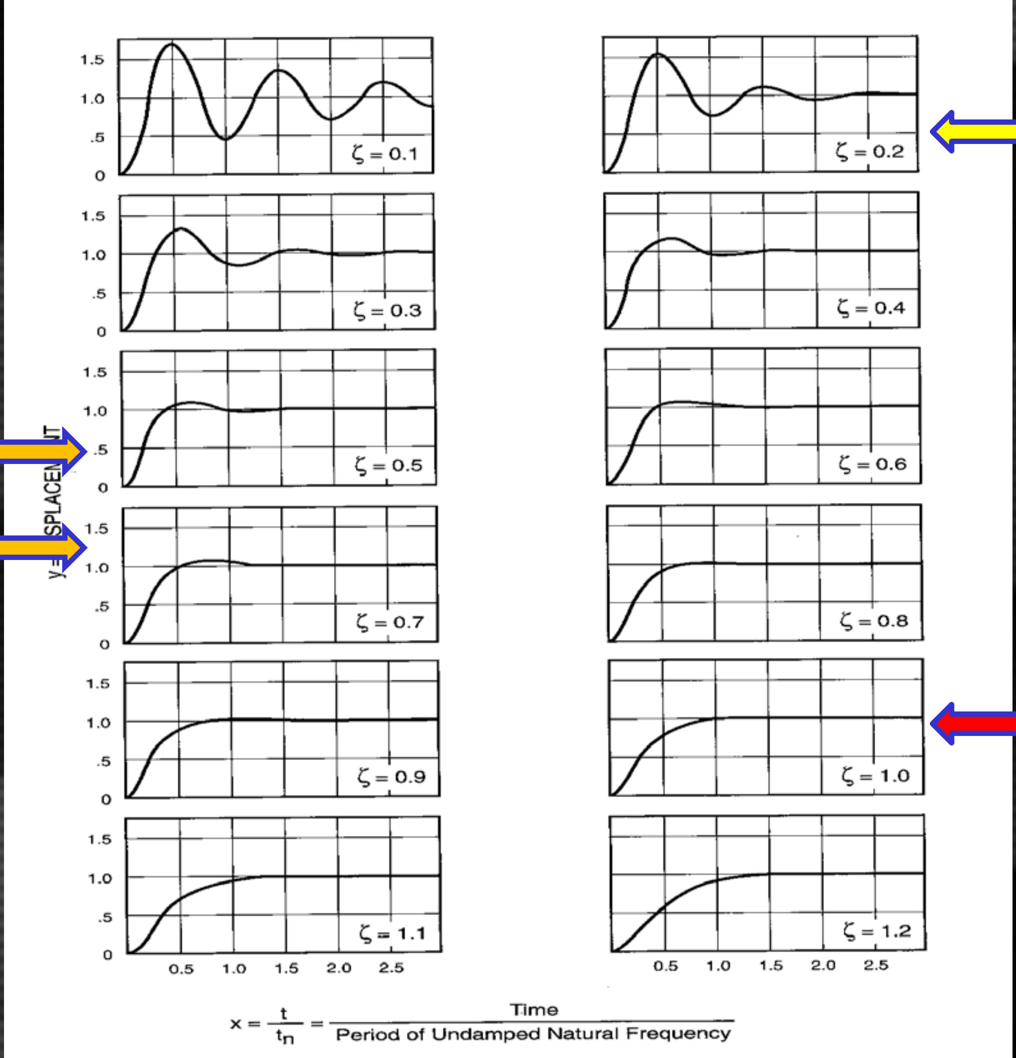
C = Damping coefficient (N-s/m)

C_{cr} = Critical damping coefficient (N-s/m)

Damping Ratio

Passenger Car

Non-Aero Racecars



Critical Damping

Aero Racecars
Ride: 0.7-1.1
Roll: 6.0-9.0

Milliken

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Calculation Roadmap

Vehicle Data

Motion Ratio

Wheel Rate
Ride Rate

Natural Frequencies
Sprung & Unsprung

Critical Damping
Sprung & Unsprung

Damping Ratio

Desired Damping Ratio

Knee Speed

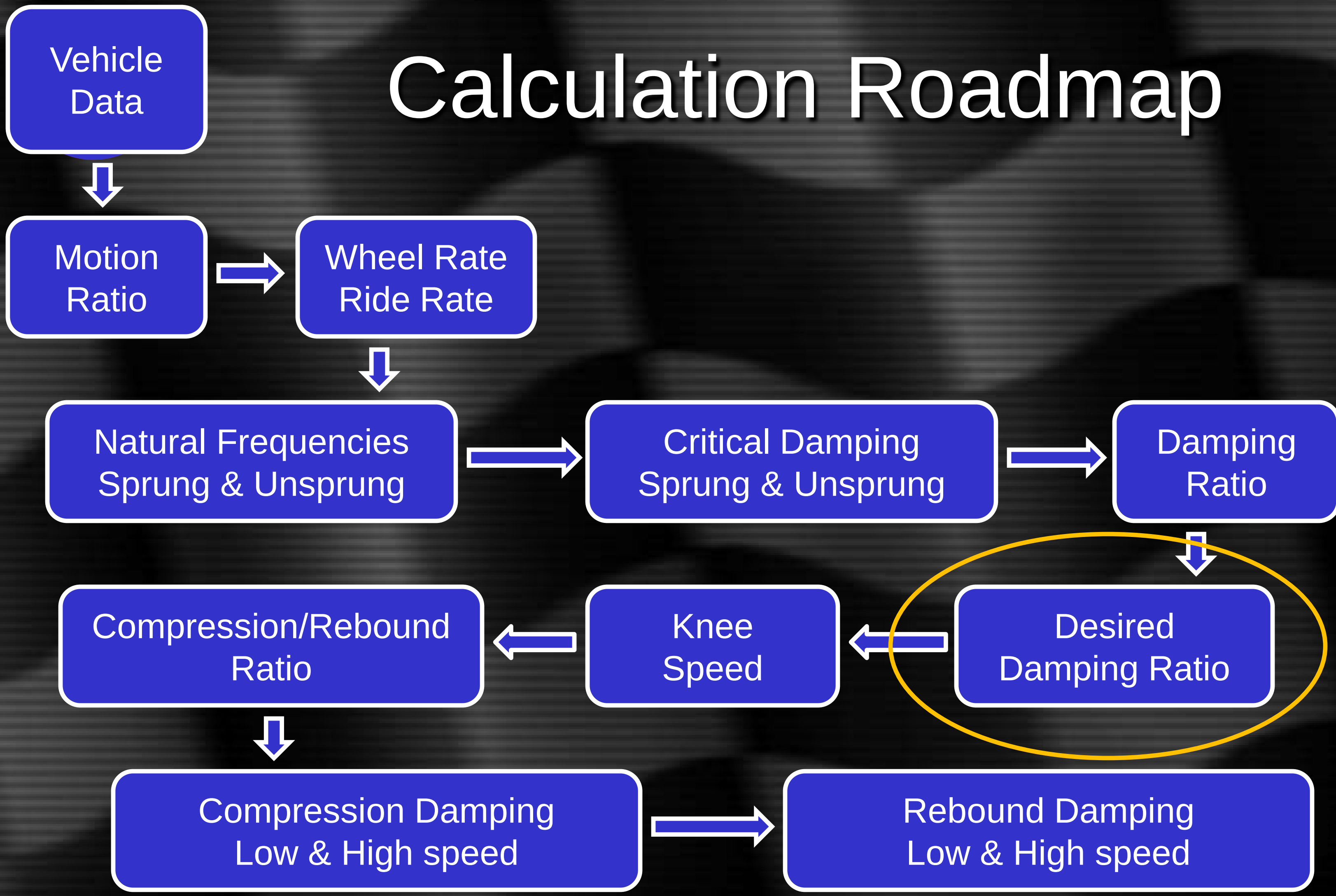
Compression/Rebound Ratio

Decisions!!

Compression Damping
Low & High speed

Rebound Damping
Low & High speed

Calculation Roadmap



Desired Damping Ratio

Damping Ratio is based on **YOUR** decisions:

- Dynamic ride frequency
- Dynamic pitch frequency
- Dynamic roll rate
- Spring rates
- Sway bar rates
- Driver preferences

Desired Damping Ratios

Choose Damping Ratios for:

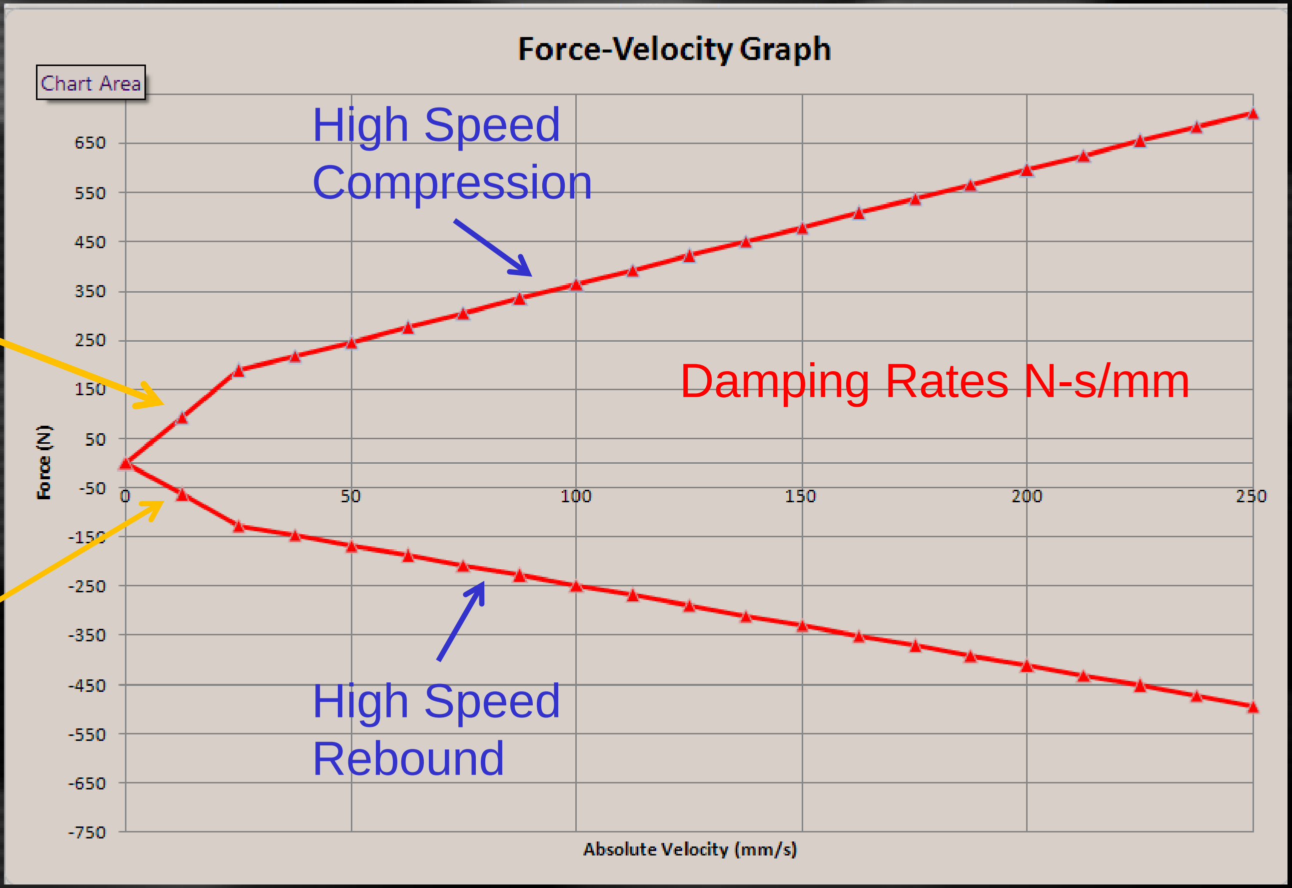
- Low speed compression
- Low speed rebound
- High speed compression
- High speed rebound

Low speed is body control and transitions, high speed is control over bumps.

Desired Damping Ratios

Low Speed Compression

Low Speed Rebound

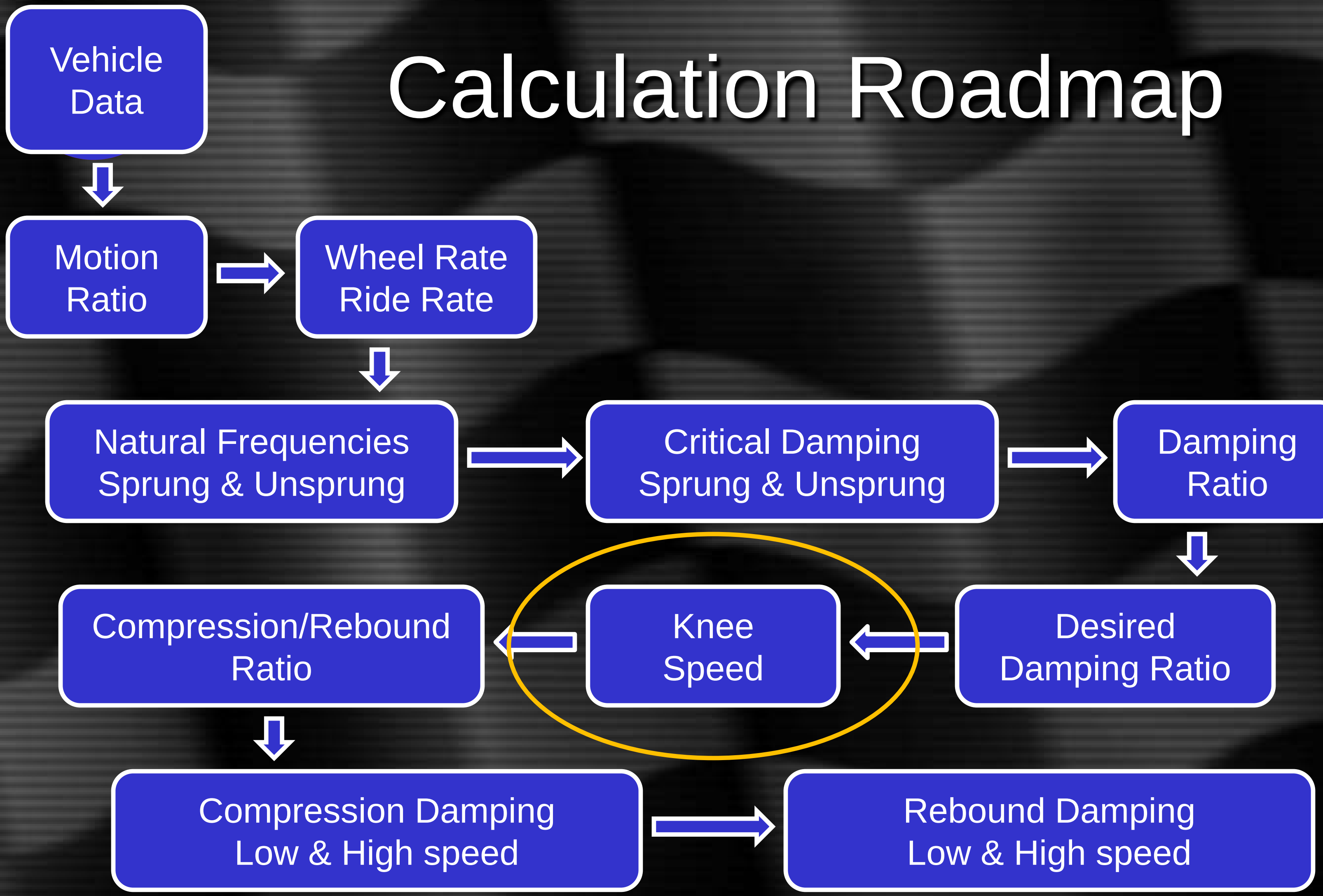


Desired Damping Ratios

Why four different damping ratios?

- Control two different masses with one damper
  - Sprung mass
  - Unsprung mass
- Damper has many functions
  - Control resonant frequencies
  - Control transient weight transfer rate

Calculation Roadmap



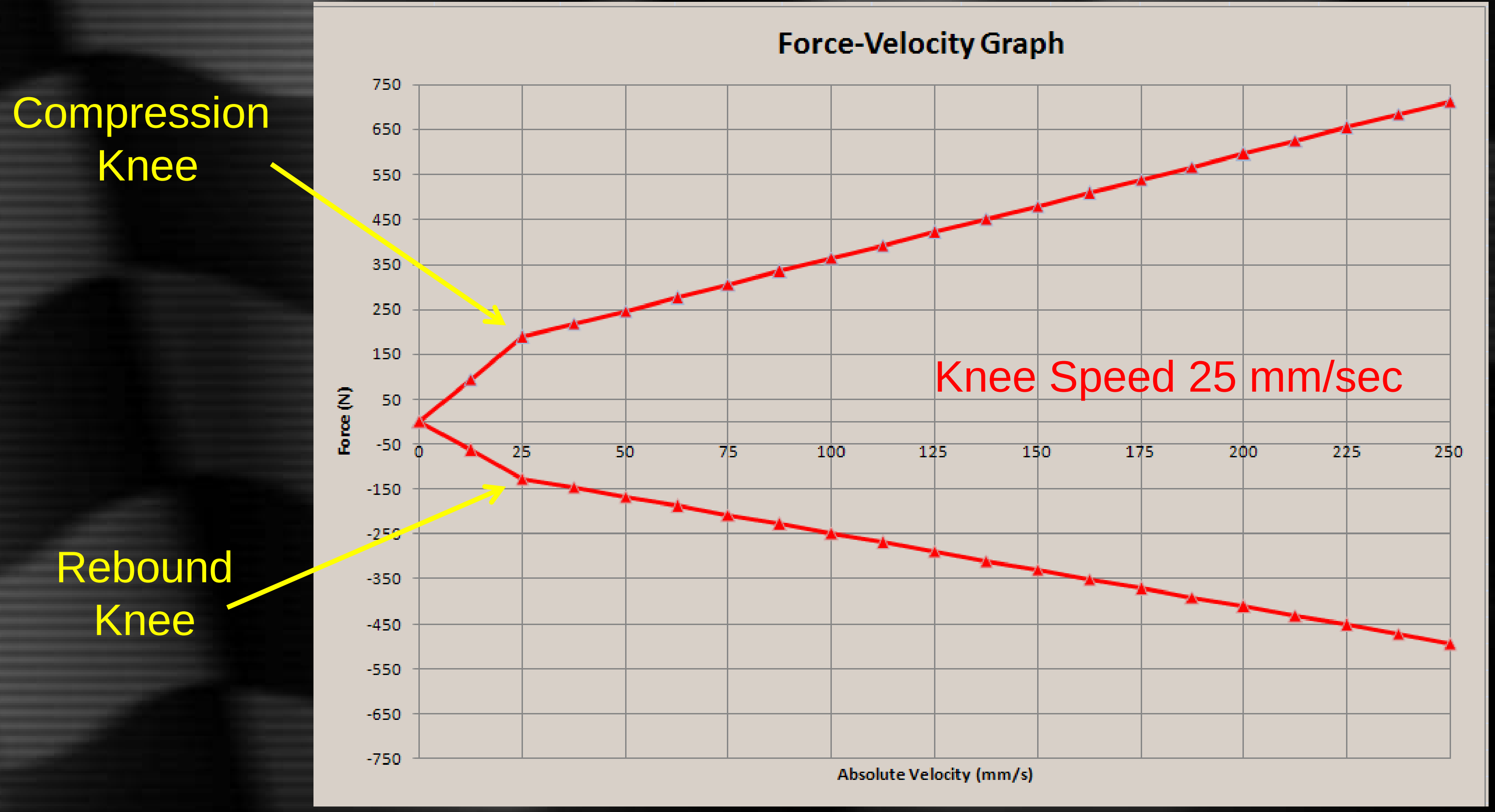
Knee Speed

Knee speed is the velocity where the damping transitions from low speed to high speed, or from the low speed Damping Ratio to the high speed Damping Ratio.

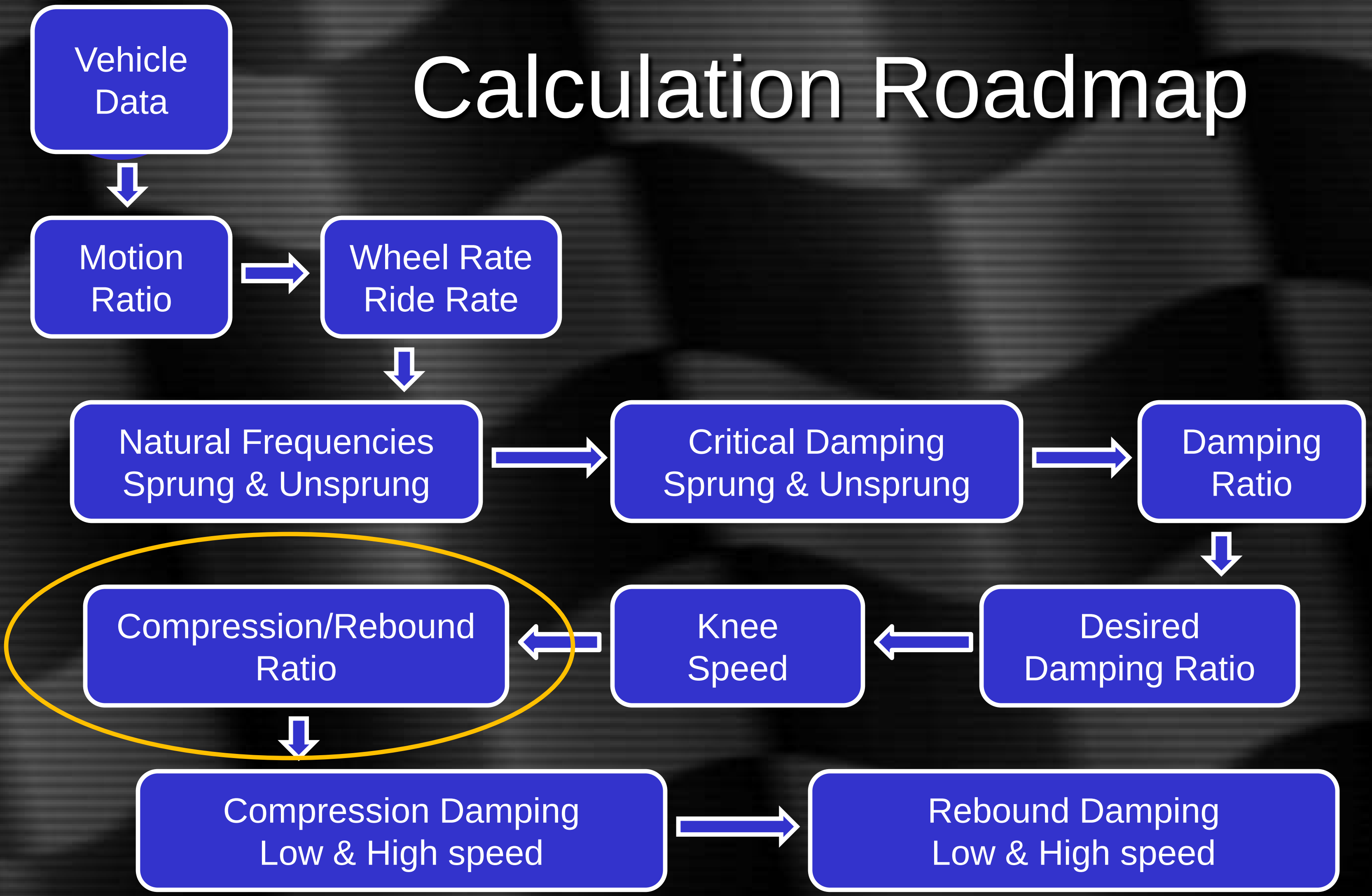
Knee speed is the transition from body control to control over bumps. Usually chosen above velocity of sprung mass resonance.

May not be able to change due to valve design

Knee Speed


Force-Velocity Graph
Compression Knee
Rebound Knee
Knee Speed 25 mm/sec
Force (N)
Absolute Velocity (mm/s)
750
650
550
450
350
250
150
50
-50
-150
-350
-450
-550
-650
-750
0
25
50
75
100
125
150
175
200
225
250

Calculation Roadmap

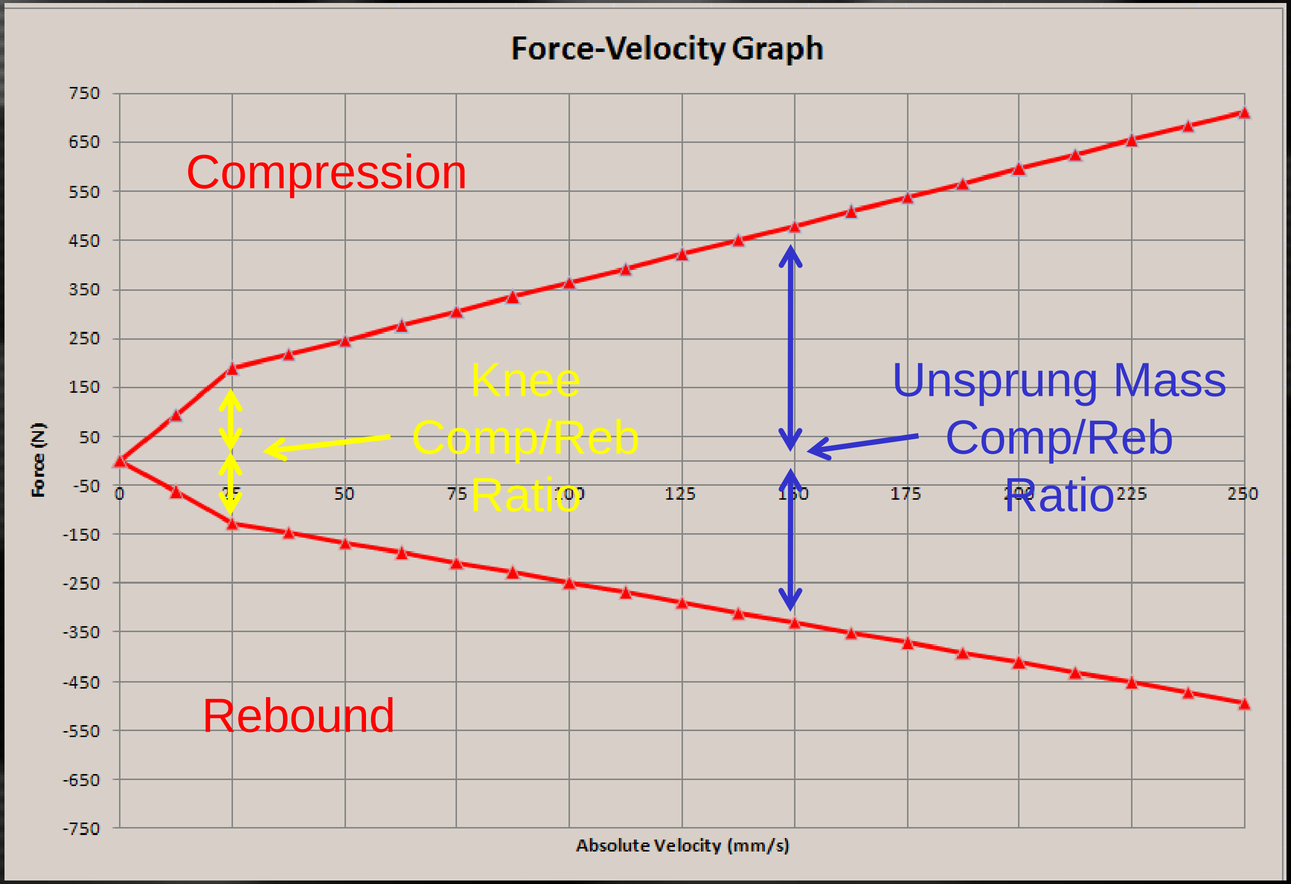


Compression to Rebound Ratio

Compression to rebound ratio is the ratio of damping force at a specified velocity.

Typically specified at the Knee Speed and velocity of unspsrung mass resonance.

Compression to Rebound Ratio



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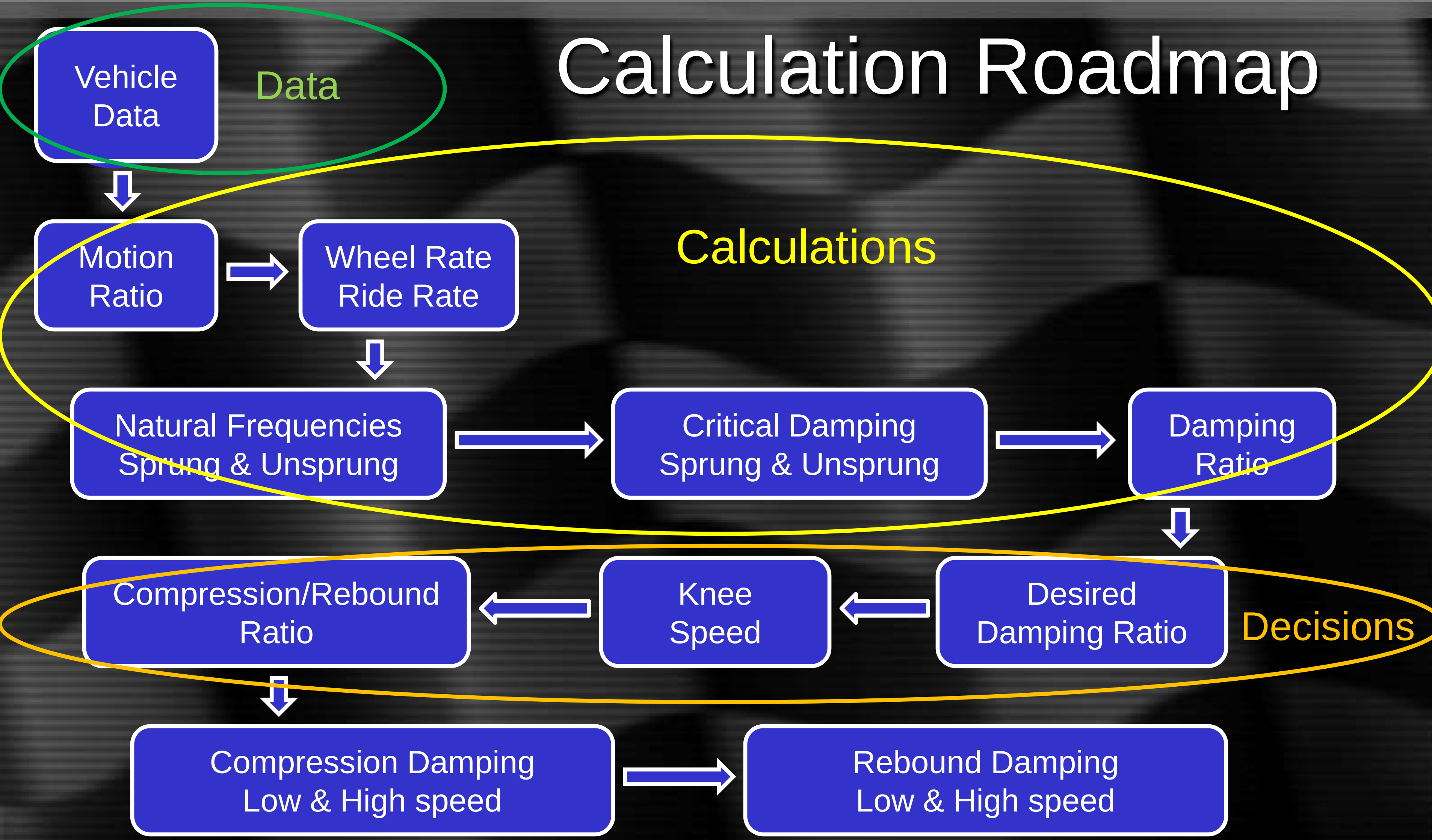
Calculation Roadmap



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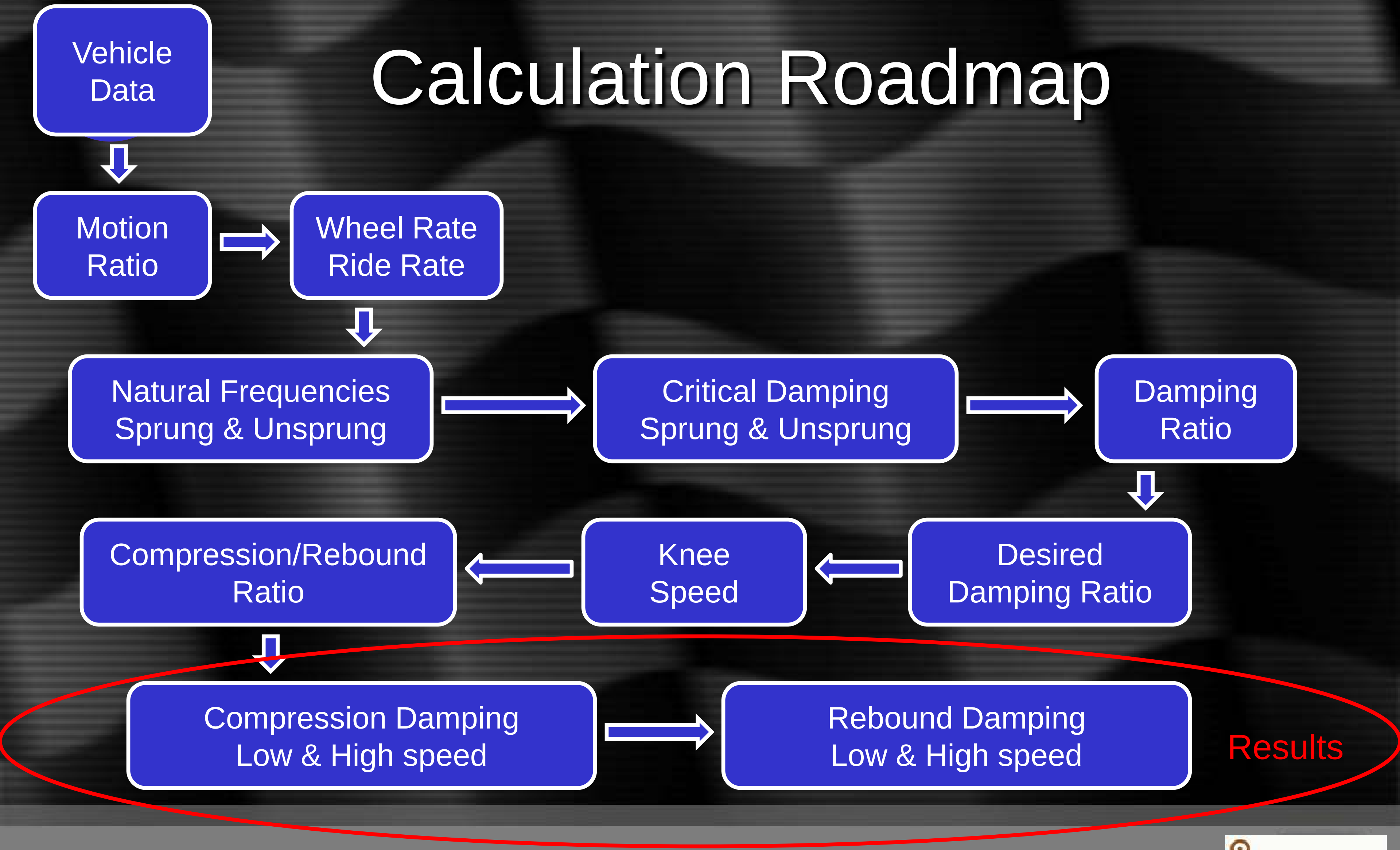

Calculations, Decisions, Results

Calculations

	Sprung Mass Critical Damping (N-s/mm)	Un-Sprung Mass Critical Damping (N-s/mm)
Front	2.11	2.62
Rear	2.36	2.91

Decisions

Desired Damping Ratio (c/c_crit)

	Lo	Hi
Front	4.00	0.90
Rear	3.20	0.80

Compression/Rebound Ratio

Knee Speed (mm/s)	Low Speed Comp.	Low Speed Reb.	High Speed Comp.	High Speed Reb.
12.5	1.5	1.0	1.0	0.7
12.5	1.5	1.0	1.0	0.7

Results

	Low Speed Compression Damping N-s/mm	Low Speed Compression Damping N at 50 mm/sec	Low Speed Rebound Damping N-s/mm	Low Speed Rebound Damping N at 50 mm/sec
Front	8.5	423	5.6	282
Rear	7.5	377	5.0	252

	High Speed Compression Damping N-s/mm	High Speed Compression Damping N at 250 mm/sec	High Speed Rebound Damping N-s/mm	High Speed Rebound Damping N at 250 mm/sec
Front	2.4	590	1.7	413
Rear	2.3	582	1.6	407

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Damping Rate

The damping rate for a specific portion of the damping curve

$$DR = C_{cr} * \varepsilon$$

DR = Damping Rate (N-s/m)
C_{cr} = Critical damping coefficient (N-s/m)
ξ = Damping Ratio (N-s/m)

Low Speed Comp Damping Rate

Calculate low speed compression damping rate using Sprung Mass Critical Damping and low speed Damping Ratio

$$DR(lsc) = C_{cr}(s) * \varepsilon(ls)$$

DR(lsc) = Low speed comp Damping Rate (N-s/m)
$C_{cr}(s)$ = Sprung mass critical damping coefficient (N-s/m)
ξ(ls) = Low speed Damping Ratio (N-s/m)

Low Speed Comp Damping Force

Calculate compression damping force at Knee Speed using low speed compression Damping Ratio and Knee Speed

$$CF(ls) = DR(lsc) * KS$$

CF(ls) = Low speed comp damping force (N)
KS = Knee Speed (mm/sec)

Calculation, Decision, Results

Calculations

Sprung Mass Critical Damping (N-s/mm)

Front	2.11
Rear	2.36

Un-Sprung Mass Critical Damping (N-s/mm)

Front	2.62
Rear	2.91

Decisions

Desired Damping Ratio (c/c_crit)

Front Lo	4.00	0.90	Front Hi
Rear Lo	3.20	0.80	Rear Hi

Knee Speed (mm/s) / **Compression/Rebound Ratio**

Knee Speed (mm/s)	Low Speed Comp.	Low Speed Reb.	High Speed Comp.	High Speed Reb.
12.5	1.5	1.0	1.0	0.7
12.5	1.5	1.0	1.0	0.7

Results

Low Speed Compression Damping / **Low Speed Rebound Damping**

	Compression N-s/mm	Compression N at 50 mm/sec	Rebound N-s/mm	Rebound N at 50 mm/sec
Front	8.5	423	5.6	282
Rear	7.5	377	5.0	252

High Speed Compression Damping / **High Speed Rebound Damping**

	Compression N-s/mm	Compression N at 250 mm/sec	Rebound N-s/mm	Rebound N at 250 mm/sec
Front	2.4	590	1.7	413
Rear	2.3	582	1.6	407

High Speed Comp Damping Rate

Calculate high speed compression damping rate using Unsprung Mass Critical Damping and high speed Damping Ratio

$$DR(hsc) = C_{cr}(us) * \varepsilon(hs)$$

DR(hsc) = High speed comp Damping Rate (N-s/m)
$C_{cr}(us)$ = Unsprung mass critical damping coefficient (N-s/m)
ξ(hs) = Low speed Damping Ratio (N-s/m)

High Speed Comp Damping Force

Calculate high speed compression damping force using high speed compression Damping Ratio and high velocity speed

$$CF(hs) = DR(hsc) * V(hs)$$

CF(hs) = High speed comp damping force (N)
V(hs) = High speed velocity(mm/sec)

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Calculation, Decision, Results

Calculations

Sprung Mass – Critical Damping (N-s/mm)

Front	2.11
Rear	2.36

Un-Sprung Mass – Critical Damping (N-s/mm)

Front	2.62
Rear	2.91

Decisions

Desired Damping Ratio (c/c crit)

	Lo	Hi	
Front Lo	4.00	0.90	Front Hi
Rear Lo	3.20	0.80	Rear Hi

Knee Speed (mm/s)

12.5
12.5

Compression/Rebound Ratio

Low Speed Comp.	Low Speed Reb.	High Speed Comp.	High Speed Reb.
1.5	1.0	1.0	0.7
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Results

Low Speed Compression Damping

	N-s/mm	N at 50 mm/sec
Front	8.5	423
Rear	7.5	377

Low Speed Rebound Damping

	N-s/mm	N at 50 mm/sec
Front	5.6	282
Rear	5.0	252

High Speed Compression Damping

	N-s/mm	N at 250 mm/sec
Front	2.4	590
Rear	2.3	582

High Speed Rebound Damping

	N-s/mm	N at 250 mm/sec
Front	1.7	413
Rear	1.6	407

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Low Speed Rebound Damping Rate

Calculate low speed rebound damping rate using low speed compression damping rate and low speed compression/rebound ratio

$$DR(lsr) = DR(lsc) * {}^{C}/_{R}\ (ls)$$

DR(lsr) = Low speed reb Damping Rate (N-s/m)
DR(lsc) = Low speed comp Damping Rate (N-s/m)

$${}^{C}/_{R}\ (ls) = \textbf{Low speed comp/reb ratio}$$

Low Speed Rebound Damping Force

Calculate low speed rebound damping force using low speed rebound Damping Ratio and low velocity speed

$$RF(ls) = DR(lsr) * V(hs)$$

RF(ls) = Low speed rebound damping force (N)
V(hs) = High speed velocity(mm/sec)

Calculation, Decision, Results

Decisions

Results

Sprung Mass Critical Damping (N-s/mm)		Un-Sprung Mass Critical Damping (N-s/mm)	
Front	2.11	Front	2.62
Rear	2.36	Rear	2.91

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Front	2.4	590	1.7	413
Rear	2.3	582	1.6	407

High Speed Rebound Damping Rate

Calculate high speed rebound damping rate using high speed compression damping rate and high speed compression/rebound ratio

$$RF(hs) = CF(hsc) * {}^{C}/_{R}\ (hs)$$

RF(hs) = High speed rebound damping force (N)

CF(hs) = High speed comp damping force (N)

$${}^{C}/_{R}\ (hs) = \boldsymbol{High\ speed\ comp/reb\ ratio}$$

High Speed Reb Damping Force

Calculate high speed rebound damping force using high speed rebound Damping Ratio and high velocity speed

$$RF(hs) = DR(hsr) * V(hs)$$

RF(hs) = High speed rebound damping force (N)
V(hs) = High speed velocity(mm/sec)

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Calculation, Decision, Results

Decisions

Results

Sprung Mass Critical Damping (N-s/mm)

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Rear	2.36

Un-Sprung Mass Critical Damping (N-s/mm)

Front	2.62
Rear	2.91

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Decisions

Decisions

	Sprung Mass Critical Damping (N-s/mm)		Un-Sprung Mass Critical Damping (N-s/mm)
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Front	8.5	423	5.6	282
Rear	7.5	377	5.0	252

	High Speed Compression Damping N-s/mm	High Speed Compression Damping N at 250 mm/sec	High Speed Rebound Damping N-s/mm	High Speed Rebound Damping N at 250 mm/sec
Front	2.4	590	1.7	413
Rear	2.3	582	1.6	407

Decision Example - Passenger Car

Vehicle Data

Total Weight (kg)	Front Motion Ratio (shock/wheel)
1530	1.00
Front Weight %	Front Spring Rate (N/mm)
57.1	22.2
Front Unsprung - per corner (kg)	Rear Motion Ratio (shock/wheel)
27.2	1.00
Rear Unsprung - per corner (kg)	Rear Spring Rate (N/mm)
31.8	16.2

Tire Spring Rate (N/mm)

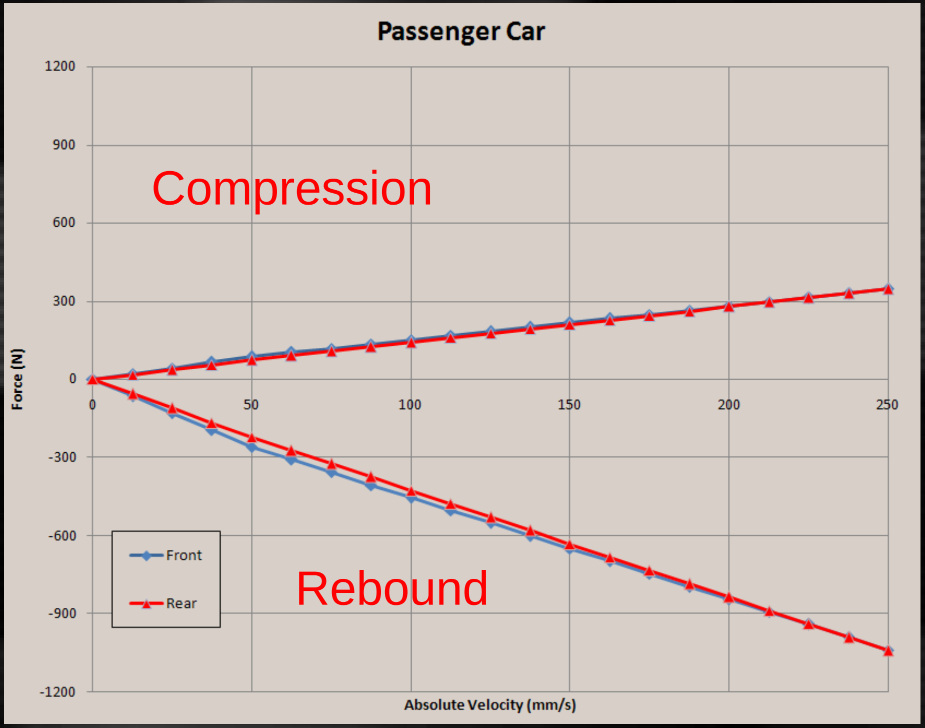
225.7	225.7
218.7	218.7

Desired Damping Ratio (c/c_crit)

	Lo	Hi	
Front Lo	0.30	0.25	Front Hi
Rear Lo	0.35	0.25	Rear Hi

Compression/Rebound Ratio

Knee Speed (mm/s)	Low Speed Comp.	Low Speed Reb.	High Speed Comp.	High Speed Reb.
50.0	1.0	3.0	1.0	3.0
50.0	1.0	3.0	1.0	3.0



Decision Example

Non-Aero Car

Vehicle Data

Total Weight (kg)	Front Motion Ratio (shock/wheel)
726	1.00
Front Weight %	Front Spring Rate (N/mm)
40.0	280
Front Unsprung - per corner (kg)	Rear Motion Ratio (shock/wheel)
27.2	1.00
Rear Unsprung - per corner (kg)	Rear Spring Rate (N/mm)
31.8	364

Tire Info	Tire Spring Rate (N/mm)	
Size:		
Brand:	525	525
Compound:	525	525

Desired Damping Ratio (c/c_crit)

Front Lo	0.71	0.40	Front Hi
Rear Lo	0.71	0.40	Rear Hi

Compression/Rebound Ratio

Knee Speed (mm/s)	Low Speed Comp.	Low Speed Reb.	High Speed Comp.	High Speed Reb.
25.0	1.0	3.0	1.0	2.0
25.0	1.0	3.0	1.0	2.0

Indy Car - Aero

Vehicle Data

Total Weight (kg)	Front Motion Ratio (shock/wheel)
726	1.00
Front Weight %	Front Spring Rate (N/mm)
40.0	525
Front Unsprung - per corner (kg)	Rear Motion Ratio (shock/wheel)
27.2	1.00
Rear Unsprung - per corner (kg)	Rear Spring Rate (N/mm)
31.8	612

Tire Info	Tire Spring Rate (N/mm)	
Size:		
Brand:	787	787
Compound:	787	787

Desired Damping Ratio (c/c_crit)

Front Lo	6.00	0.90	Front Hi
Rear Lo	6.00	0.70	Rear Hi

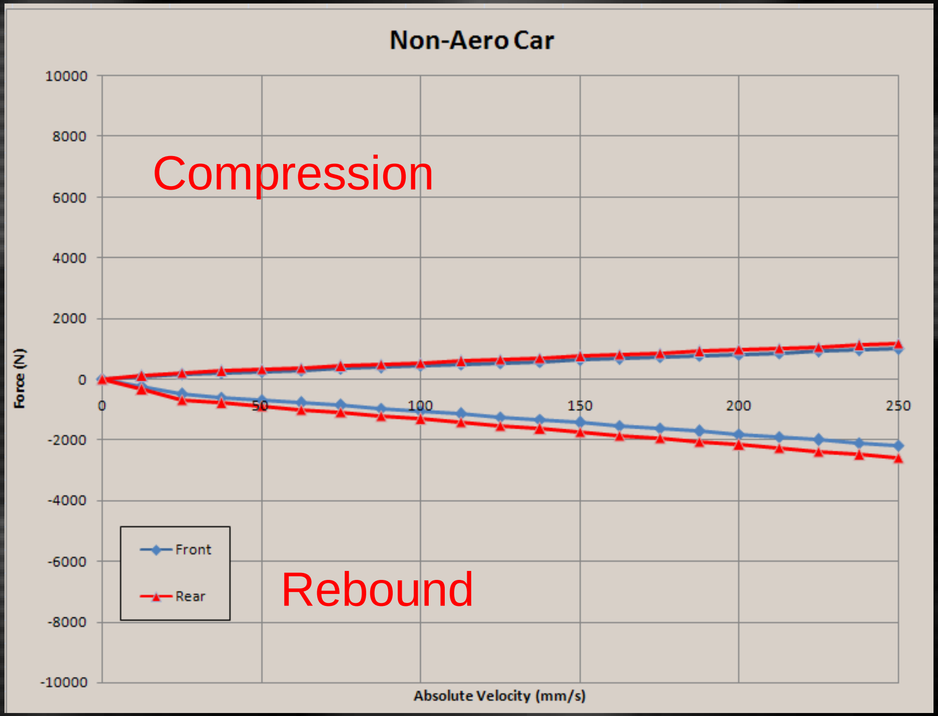
Compression/Rebound Ratio

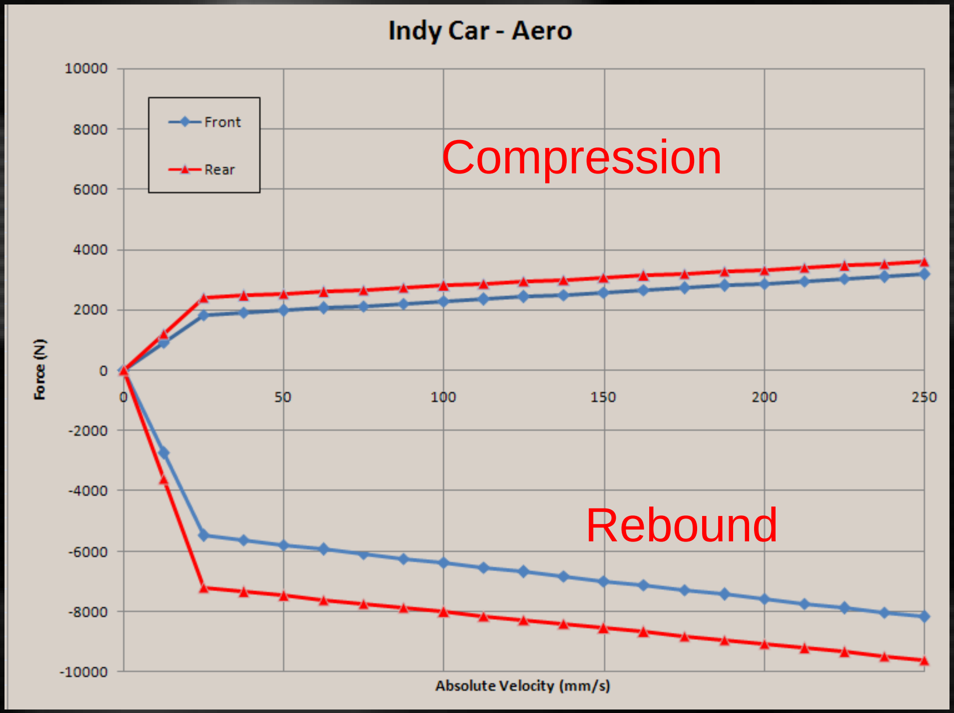
Knee Speed (mm/s)	Low Speed Comp.	Low Speed Reb.	High Speed Comp.	High Speed Reb.
25.0	1.0	3.0	1.0	2.0
25.0	1.0	3.0	1.0	2.0

Decision Example

Non-Aero Car

Indy Car - Aero





Decision Example – DP Cars

DP Car #1 | DP Car #2

Vehicle Data

Total Weight (kg): 1168	Front Motion Ratio (shock/wheel): 0.90
Front Weight %: 46.6	Front Spring Rate (N/mm): 140
Front Unsprung - per corner (kg): 45.4	Rear Motion Ratio (shock/wheel): 0.83
Rear Unsprung - per corner (kg): 45.4	Rear Spring Rate (N/mm): 122

Tire Info

	Tire Spring Rate (N/mm)	
Size:		
Brand:	262	262
Compound:	262	262

DP Car #1

Desired Damping Ratio (c/c_crit)

Front Lo	0.54	0.65	Front Hi
Rear Lo	1.20	0.85	Rear Hi

Knee Speed (mm/s)

50.0
75.0

Compression/Rebound Ratio

Low Speed		High Speed	
Comp.	Reb.	Comp.	Reb.
1.0	1.7	1.0	0.7
1.6	1.0	1.1	1.0

DP Car #2

Desired Damping Ratio (c/c_crit)

Front Lo	0.65	0.75	Front Hi
Rear Lo	1.20	0.90	Rear Hi

Knee Speed (mm/s)

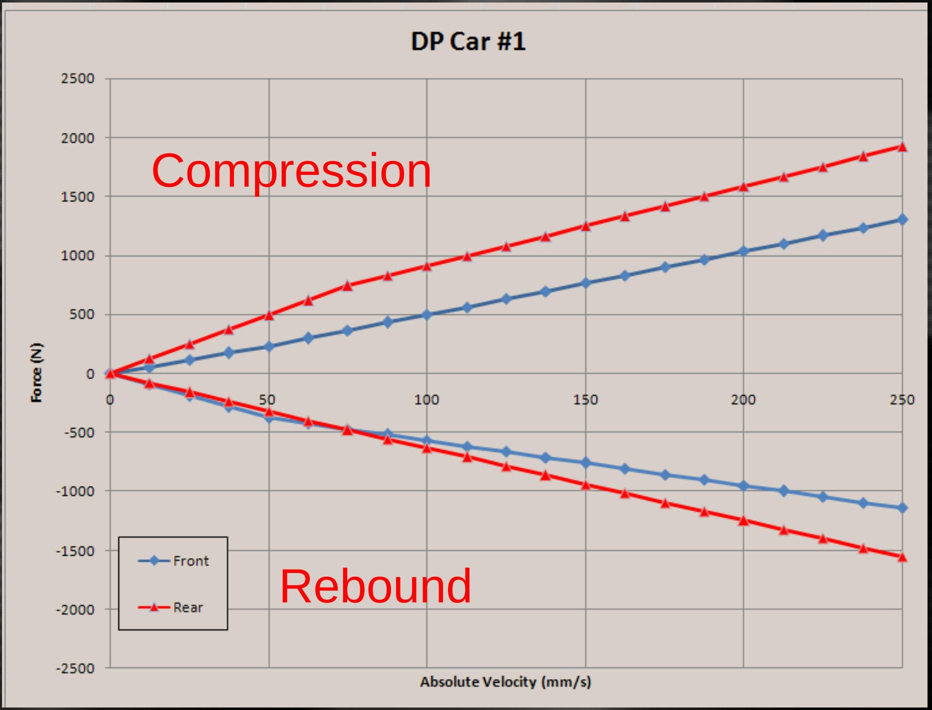
12.5
12.5

Compression/Rebound Ratio

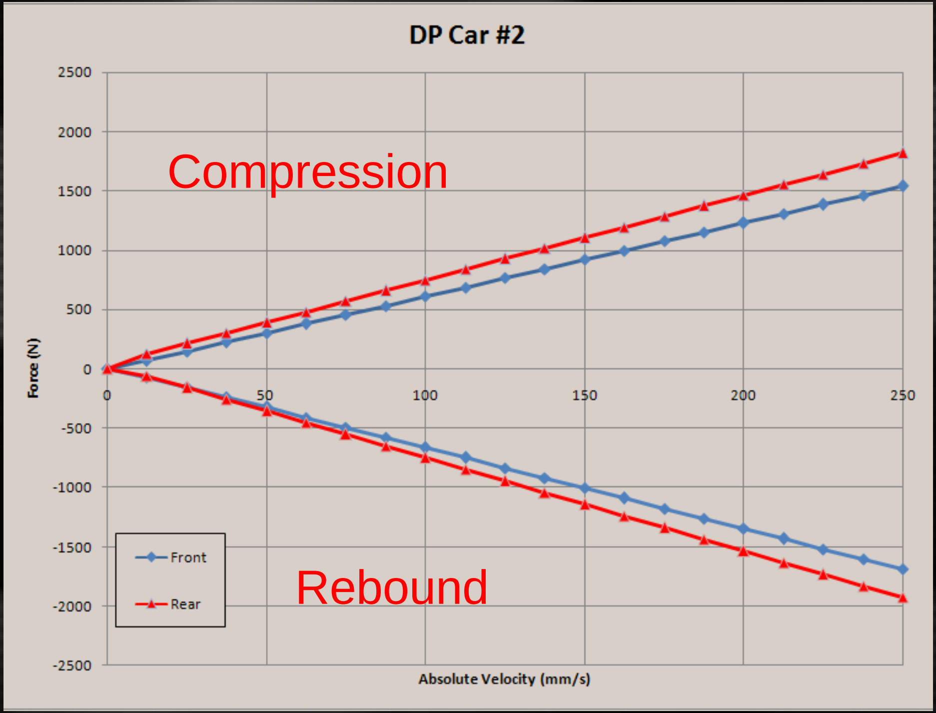
Low Speed		High Speed	
Comp.	Reb.	Comp.	Reb.
1.0	1.0	1.0	1.1
2.0	1.0	1.0	1.1

Decision Example – DP Cars

DP Car #1



DP Car #2



KAZ TECHNOLOGIES

Decision Example – FSAE Cars

Typical FSAE / Kaz Tech Approach

Vehicle Data

Total Weight (kg): 285	Front Motion Ratio (shock/wheel): 1.00
Front Weight %: 48.0	Front Spring Rate (N/mm): 21.9
Front Unsprung - per corner (kg): 10.0	Rear Motion Ratio (shock/wheel): 1.00
Rear Unsprung - per corner (kg): 12.0	Rear Spring Rate (N/mm): 26.3
	Tire Spring Rate (N/mm): 150, 150 / 150, 150

Typical FSAE

Desired Damping Ratio (c/c_crit)

Front Lo	0.40	0.40	Front Hi
Rear Lo	0.40	0.40	Rear Hi

Compression/Rebound Ratio

Knee Speed (mm/s)	Low Speed Comp.	Low Speed Reb.	High Speed Comp.	High Speed Reb.
12.5	1.0	2.0	1.0	2.0
12.5	1.0	2.0	1.0	2.0

Kaz Tech Approach

Desired Damping Ratio (c/c_crit)

Front Lo	4.00	0.90	Front Hi
Rear Lo	3.20	0.80	Rear Hi

Compression/Rebound Ratio

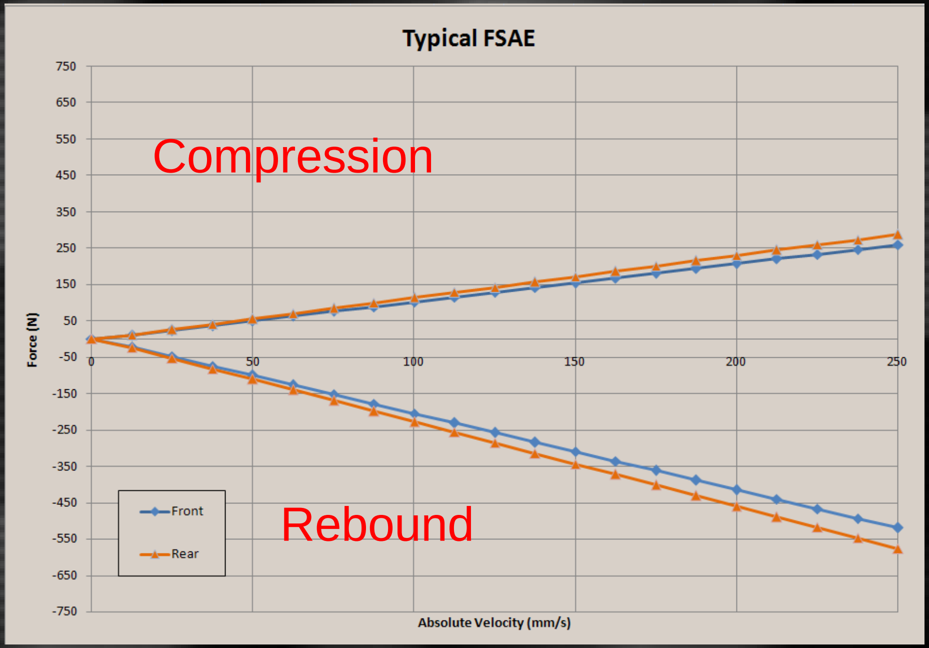
Knee Speed (mm/s)	Low Speed Comp.	Low Speed Reb.	High Speed Comp.	High Speed Reb.
12.5	1.5	1.0	1.0	0.7
12.5	1.5	1.0	1.0	0.7

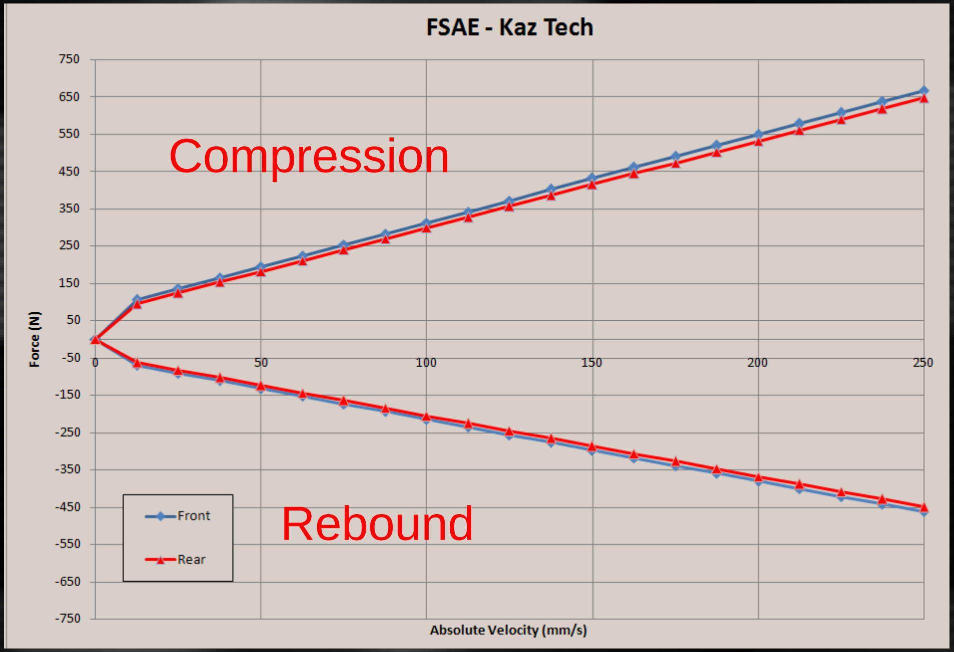
KAZ TECHNOLOGIES

Decision Example

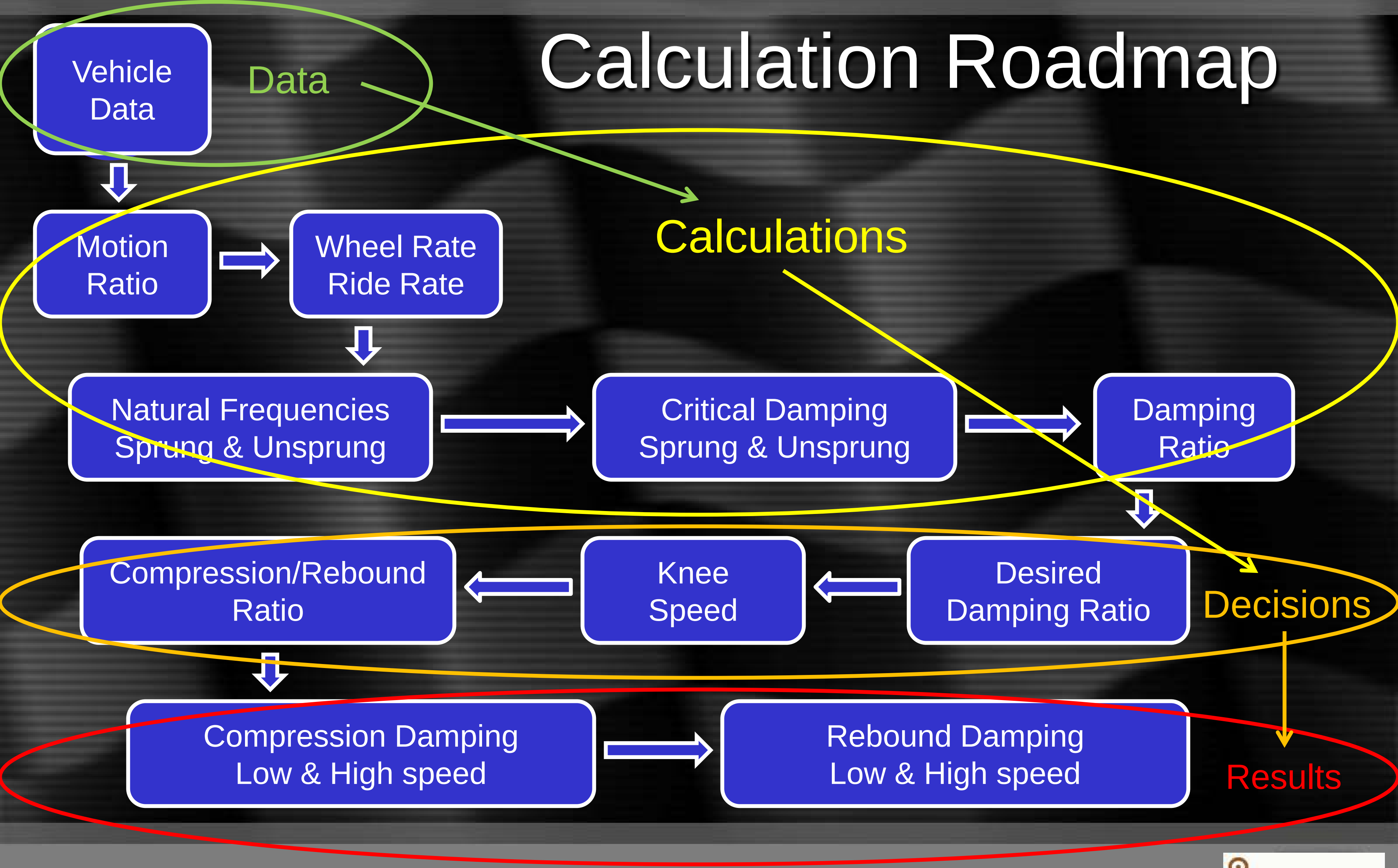
Typical FSAE

Kaz Tech Approach





Calculation Roadmap



Decisions

Decisions

	Sprung Mass Critical Damping (N-s/mm)	Un-Sprung Mass Critical Damping (N-s/mm)
Front	2.11	2.62
Rear	2.36	2.91

Desired Damping Ratio (c/c_crit)

	Lo	Hi
Front	4.00	0.90
Rear	3.20	0.80

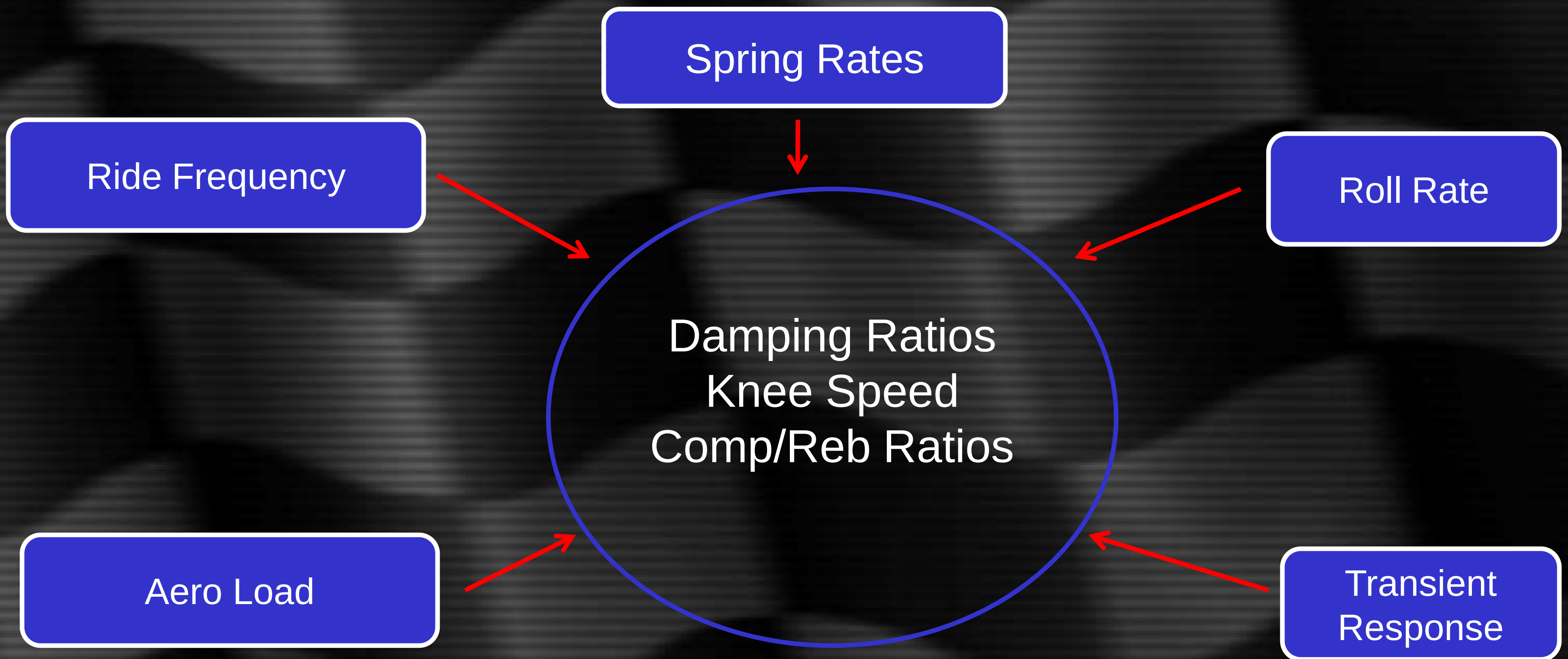
Compression/Rebound Ratio

Knee Speed (mm/s)	Low Speed Comp.	Low Speed Reb.	High Speed Comp.	High Speed Reb.
12.5	1.5	1.0	1.0	0.7
12.5	1.5	1.0	1.0	0.7

	Low Speed Compression Damping N-s/mm	Low Speed Compression Damping N at 50 mm/sec	Low Speed Rebound Damping N-s/mm	Low Speed Rebound Damping N at 50 mm/sec
Front	8.5	423	5.6	282
Rear	7.5	377	5.0	252

	High Speed Compression Damping N-s/mm	High Speed Compression Damping N at 250 mm/sec	High Speed Rebound Damping N-s/mm	High Speed Rebound Damping N at 250 mm/sec
Front	2.4	590	1.7	413
Rear	2.3	582	1.6	407

Decisions


Spring Rates
Ride Frequency
Roll Rate
Damping Ratios
Knee Speed
Comp/Reb Ratios
Aero Load
Transient Response

Low & High Freq Damping Ratios

Why two Damping Ratios?

- Low Frequency
  - Ride motions
  - Turn-in
  - Brake dive
  - Acceleration rise/squat
- High Frequency
  - Control over bumps
  - Wheel hop

Low Frequency Damping Ratio

Why high Low Frequency Damping Ratios?

- Compression
  - Load outside tire on turn-in (reduce turn-in understeer)
  - Reduce rate of brake dive (even load distribution)
  - Reduce squat on acceleration (reduce understeer)
- Rebound
  - Reduce roll
  - Reduce rear lift in braking (even load distribution)
  - Reduce front lift on acceleration (reduce understeer)

High Frequency Damping Ratio

Why less High Frequency than Low Frequency Damping Ratio?

- High frequency primarily damping wheel
- Less weight to control, thus less damping required

General Setup Examples

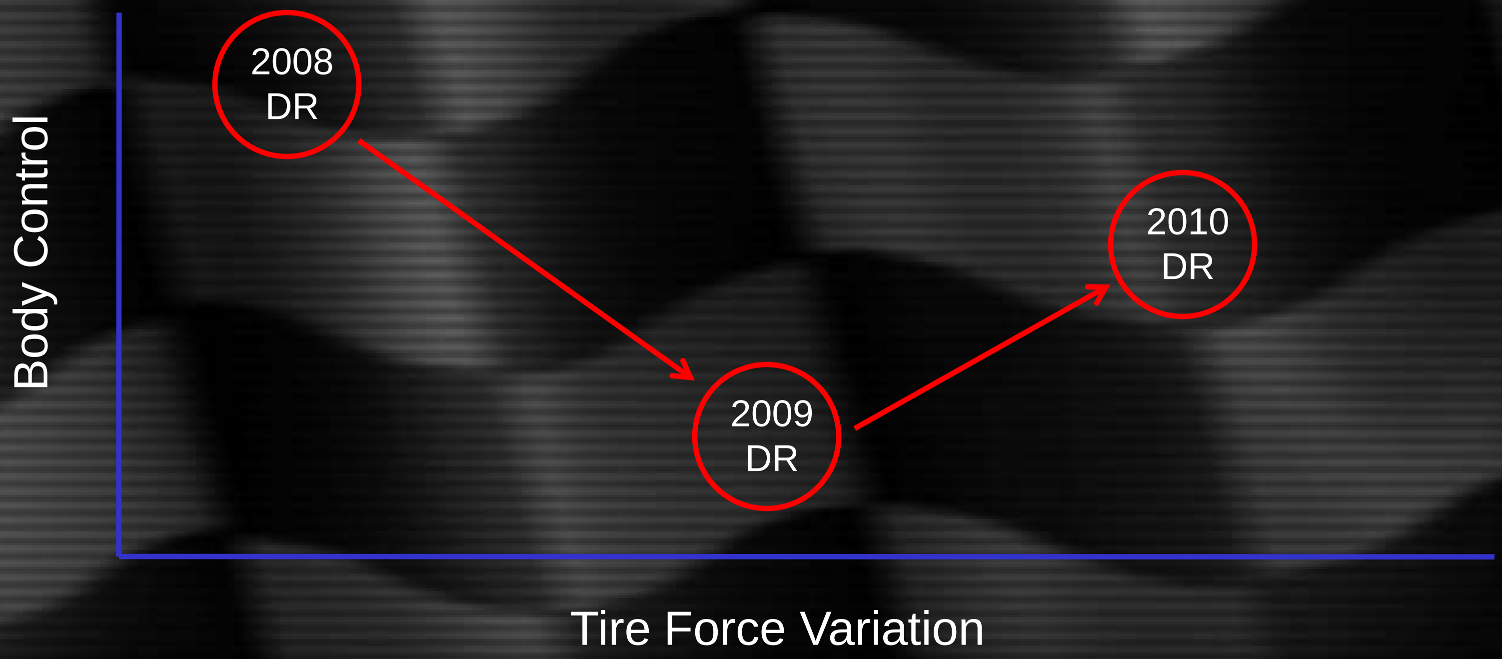
- Soft spring
- Stiff sway bar
- High compression, low rebound damping ratios

OR

- Stiff springs
- Soft sway bar
- Low compression, high rebound damping ratios

Decision Numbers

Decision Numbers are JUST numbers!!



Summary

KAZ TECHNOLOGIES

Summary

Many factors effect your damping decision

- Suspension design (Roll Center, Motion Ratio, etc.)
- Suspension variables (spring rates, bar rates,etc.)
- Tires
- Downforce
- Driver preference
- On and on…

Summary

Damping is just one part of the SYSTEM

- Damping has to work in concert with the other components
- They all have to work together
- You can achieve the objective in multiple ways

The Last Word

The Last Word

Damping calculations are a way to quantify normalized results

They are NOT the conclusion

They are the MEANS to the END!

The Last Word

Like any other variable on the car, your damping decisions are JUST numbers!

- Choose these based on all the other factors in the car

There are MULTIPLE right solutions!

Questions?

References

Books by Carroll Smith

- Tune to Win
- Drive to Win
- Prepare to Win
- Engineer to Win
- Nuts, Bolts, Fasteners and Plumbing Handbook
- Engineer In Your Pocket

References

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

Kaz Technologies

http://www.kaztechnologies.com

- Information about Kaz Technologies
- Product information
- FSAE damper drawings, CAD and damping info
- Tech Tips
- Seminar downloads
- e-Store for FSAE products

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Questions?

FSAE_Shock@kaztechnologies.com

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Kaz Technologies

Jim Kasprzak
jkaz@kaztechnologies.com
248-855-3355

Tom Jaworski
tjaworski@kaztechnologies.com
734-536-3218

Jess Youngblood
jess@kaztechnologies.com

Kaz Technologies

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Thanks!