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Design and Development of a New Suspension System for the Caterham SV-R

Presented by: Jay O'Connell, Multimatic Vehicle Engineering Manager

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Vehicle Engineering

Multimatic has engineered a number of complete vehicle and chassis systems for both niche road car and race applications

OEM Sports Car #1

OEM Sports Car #2

Viper Competition Coupe

Panoz LM-GT

Lola B2K/40

Multimatic Ford Focus Daytona Prototype

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Caterham SV Suspension — Overview

- **Presentation Overview**
  - **Project Scope**
  - **Project Targets**
  - **Suspension Design**
    - **Measurement and Modeling of Existing Vehicle**
    - **New Suspension Target Setting and Optimisation**
    - **Kinematic Analysis**
    - **New Design Modeling and Detail Component Design**
  - **Suspension Development**
    - **Initial Suspension Set-Up Calculations**
    - **Dynamic Analysis including virtual 4 post rig**
    - **Prototype Assembly**
    - **Rig Testing: K+C and 4-Post Rig Tests**
    - **Road Evaluation**
    - **Track testing**
  - **Results and Conclusions**

Project Scope

- Caterham Cars Ltd. commissioned Multimatic, Inc. to design and develop new front and rear suspensions for the Roadsport SV model in 2003
- Revise the front steering geometry and replace the outboard spring-damper design with with inboard mounted dampers maintaining the same motion ratio
- Replace the de Dion rear suspension with an all new adjustable independent rear suspension

Caterham SV Suspension

- **Project Targets:**
  - **Improved ride and handling without losing the iconic character of the Caterham Seven**
  - **Improved suspension and steering kinematics**
  - **Increased adjustability (ride height, front ARB, rear camber and toe adjustability)**
  - **Reduced unsprung weight**
  - **Minimise use of new components and level of validation required**

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Caterham SV Suspension — Measurement of Existing Vehicle

- CMM measurements taken of existing frame and suspension components

Right front suspension

Left rear suspension

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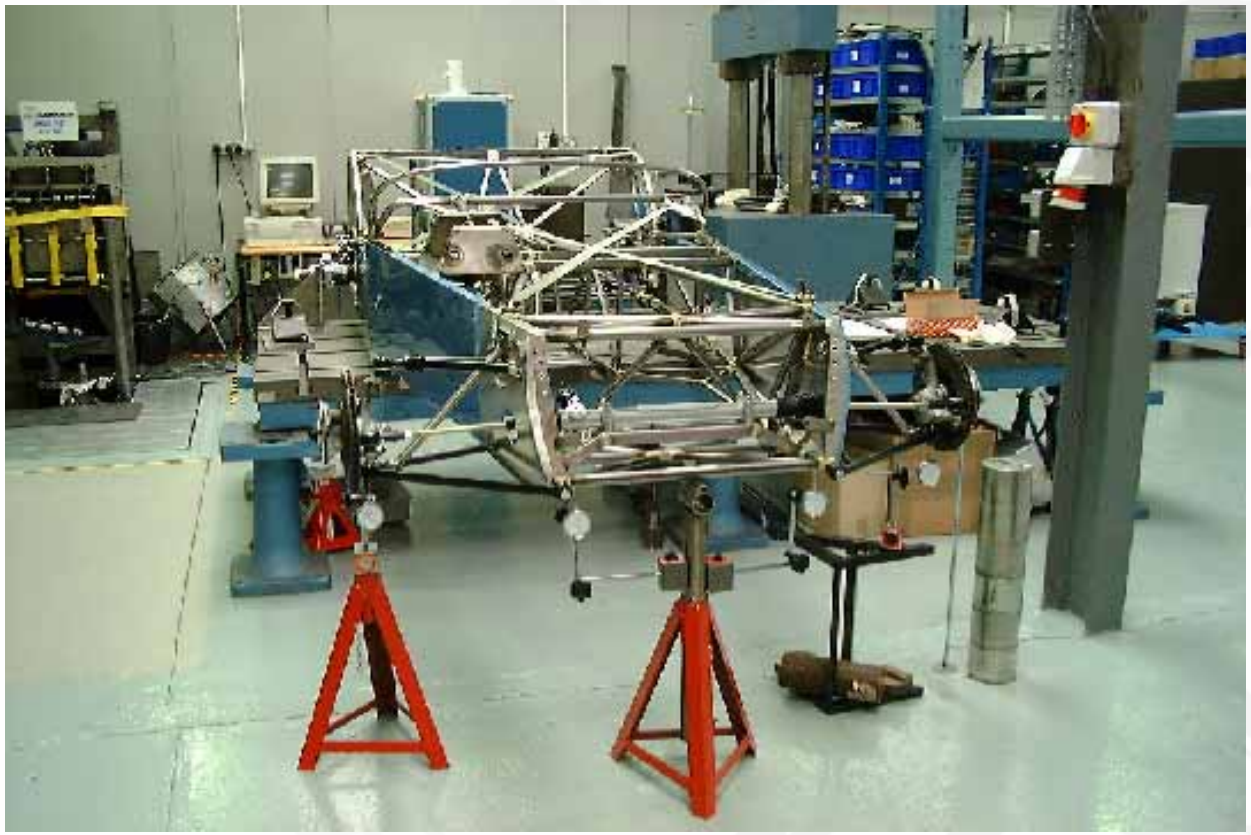
Caterham SV Suspension — Measurement of Existing Vehicle

- **Chassis compliance was measured through full vehicle torsion testing at MTCE**



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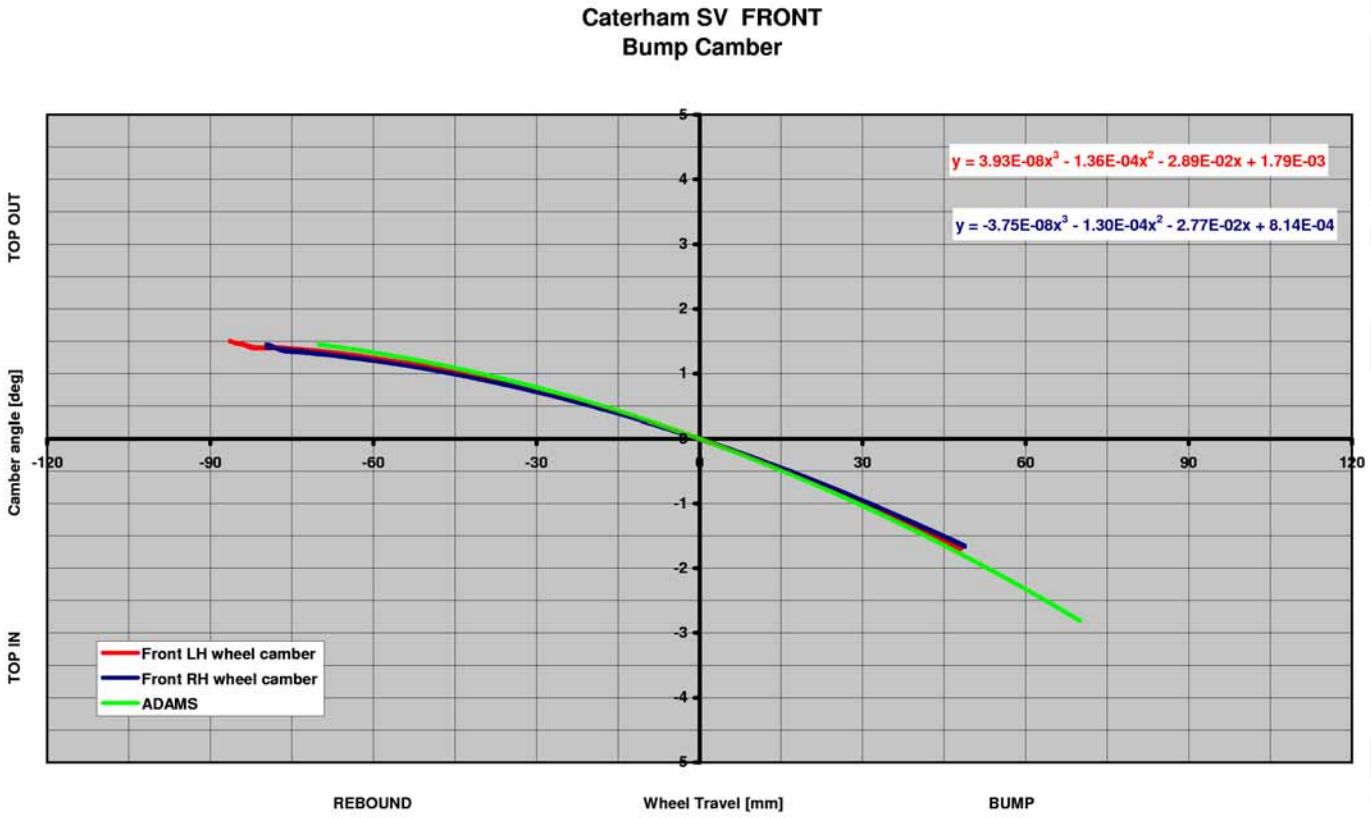
Modeling of Existing Vehicle

- **Kinematic model of standard car produced in ADAMS and validated based on correlation with K&C results**



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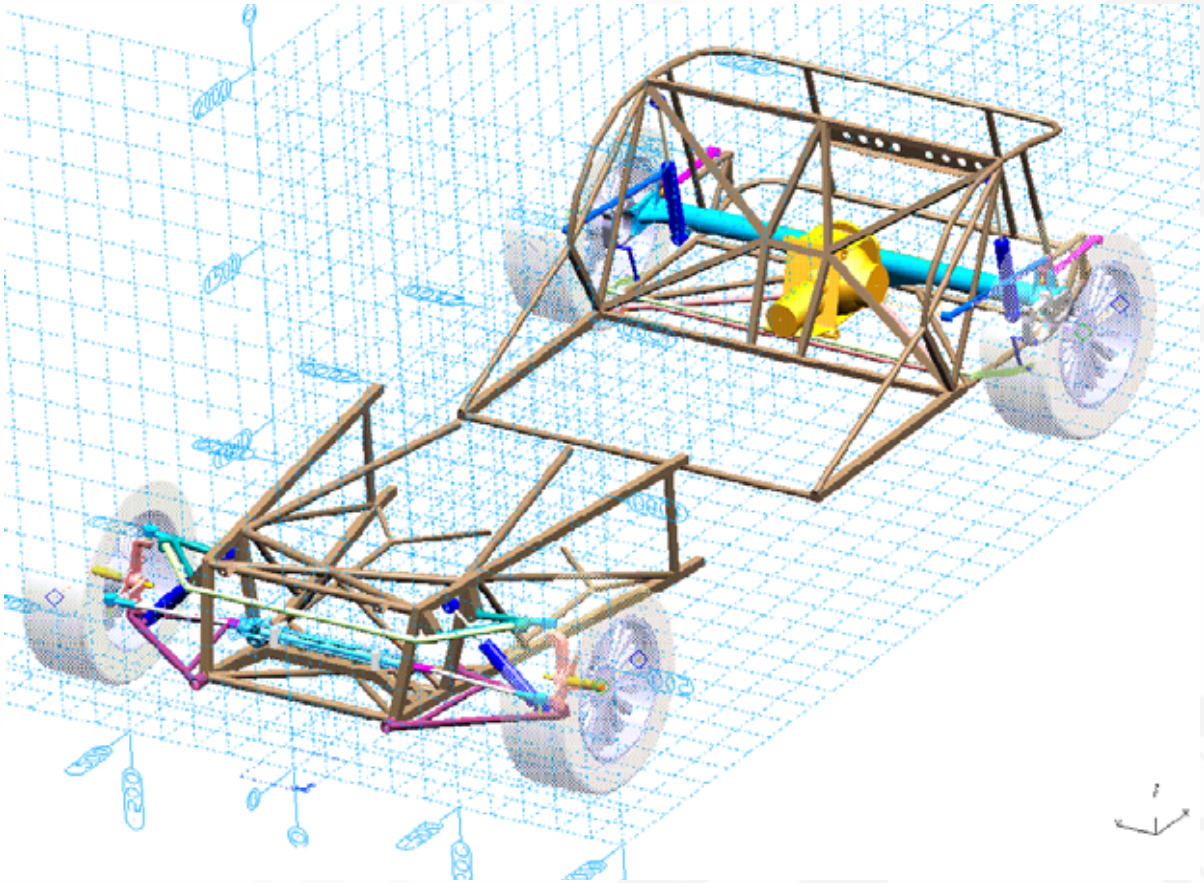
Modeling of Existing Vehicle

- SDRC I-Deas 3D CAD models were created for the existing components and assembled into a full vehicle model



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Target Setting

- **Front and Rear suspension design targets were set using desired vehicle characteristics, benchmarking and experience**

	Front Targets	Rear Targets
Caster (deg)	5.0	2.0 to 5.0
Caster trail (mm)	30.0	5.0 to 25.0
KPI (deg)	9.0 to 11.0	<12.0
Hub offset (mm)	50.0 to 60.0	40.0 to 75.0
ground offset (mm)	8.0 to 15.0	-5.0 to 20.0
Toe (deg)	-0.10	0.17
Camber (deg)	-2.00	-1.25
Roll Centre H (mm)	30.0 to 40.0	20.0 to 40.0 > Front
RC migration @3°(mm)	-10.0 to 10.0	5.0 to 15.0 < Front
Anti-Dive (%)	20.0	-
Anti-Squat (%)	-	20.0
Anti-Lift (%)	-	40.0
Bump Steer (deg/m)	-3.0 to –5.0	1.0 to 2.5
Bump Camber (deg/m)	-10.0 to –40.0	-10.0 to -40.0
Bump Caster (deg/m)	< 20.0	Minimise
Wheel Reces. (mm/m)	> 0.0	>15.0
Roll Camber (deg/deg)	0.25 to 0.30	0.35 to 0.40
Roll Steer (deg/deg)	0.04 to 0.075	-0.01 to -0.02
Ackerman (%)	40.0%	-

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Optimisation

- **Kinematics optimised using ADAMS/Car and ADAMS/Motorsport against baseline targets**
- **Proposals reviewed and compared against CAD data for design and manufacturing feasibility**

54373 - Caterham SV

SV geometry targets

June 17, 2003

FRONT SUSPENSION

Proposal C:

Objectives: Widen the front track to correspond to the rear one
Constraints: Use the existing upright, hub, lower A-Arm position
Modifications: Hub shifted outboard to match new front track.

		Front Suspension		
	TARGET	SV original	Proposal B	Proposal C
Caster (deg)	*5*	7.7	4.7	4.8
Caster trail (mm)	*30*	33	24	24
KPI (deg)	*9 to 11*	11.2	10.9	10.9
Hub offset (mm)	*50 to 60*	**100**	**75**	**75**
ground offset (mm)	*8 to 15*	**61.5**	**36.5**	**36.5**
Toe (deg)	*-0.1*	-0.28	-0.33	-0.34
Camber (deg)	*-2.0*	-2.3	-2.1	-2.1
Roll Centre H (mm)	*30 to 40*	**62**	32.2	33
RC migration @3°(mm)	*-10 to 10*	-0.9	-3.6	-4.1
Anti-Dive (%)	*20*	**72**	**57**	**57.6**
Anti-Squat (%)	*-*	-	-	-
Anti-Lift (%)	*-*	-	-	-
Bump Steer (deg/m)	*-3 to -5*	-1.6	-4.0	-4.2
Bump Camber (deg/m)	*-10 to -40*	-30	-17	-17
Bump Caster (deg/m)	*<20*	**39**	**29**	**29**
Wheel Reces. (mm/m)	*>0*	9	2.2	1.9
Roll Camber (deg/deg)	*0.25 to 0.30*	**0.39**	**0.22**	**0.22**
Roll Steer (deg/deg)	*0.04 to 0.075*	0.02	0.05	0.05
Ackerman (%)	*40%*	32% (1 rev)	33% (1 rev)	32% (1 rev)

**** All values valid for ride height 2UP condition with CR500 195/45 R15 tyre.***

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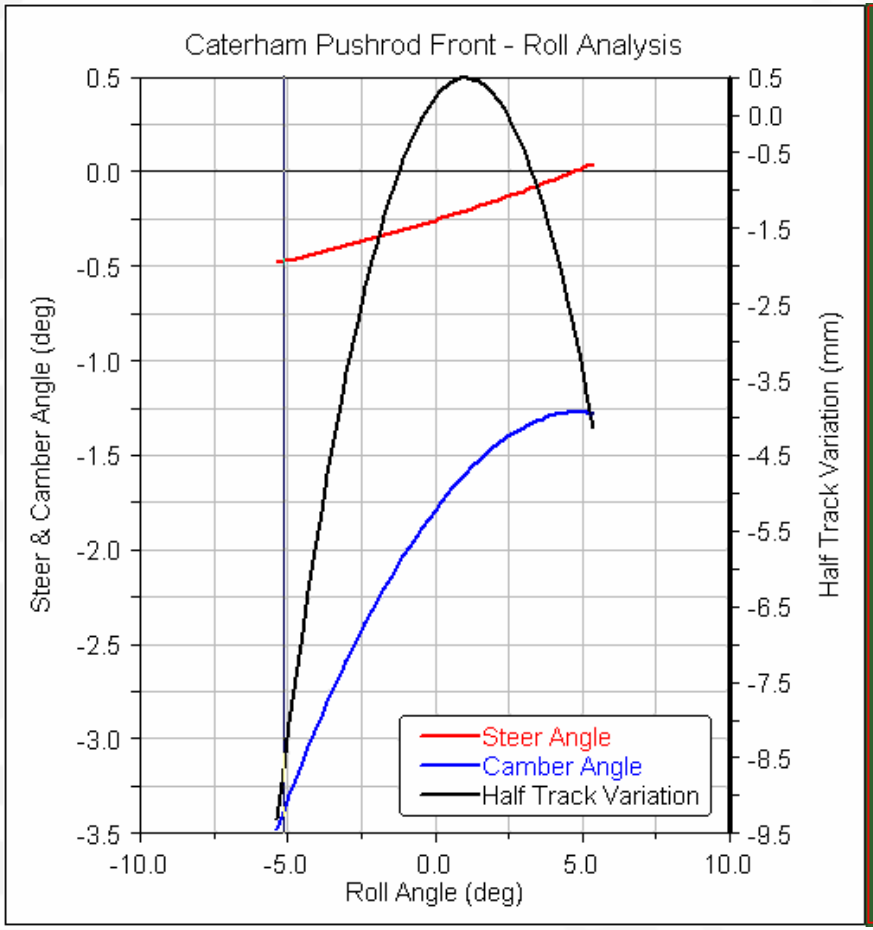
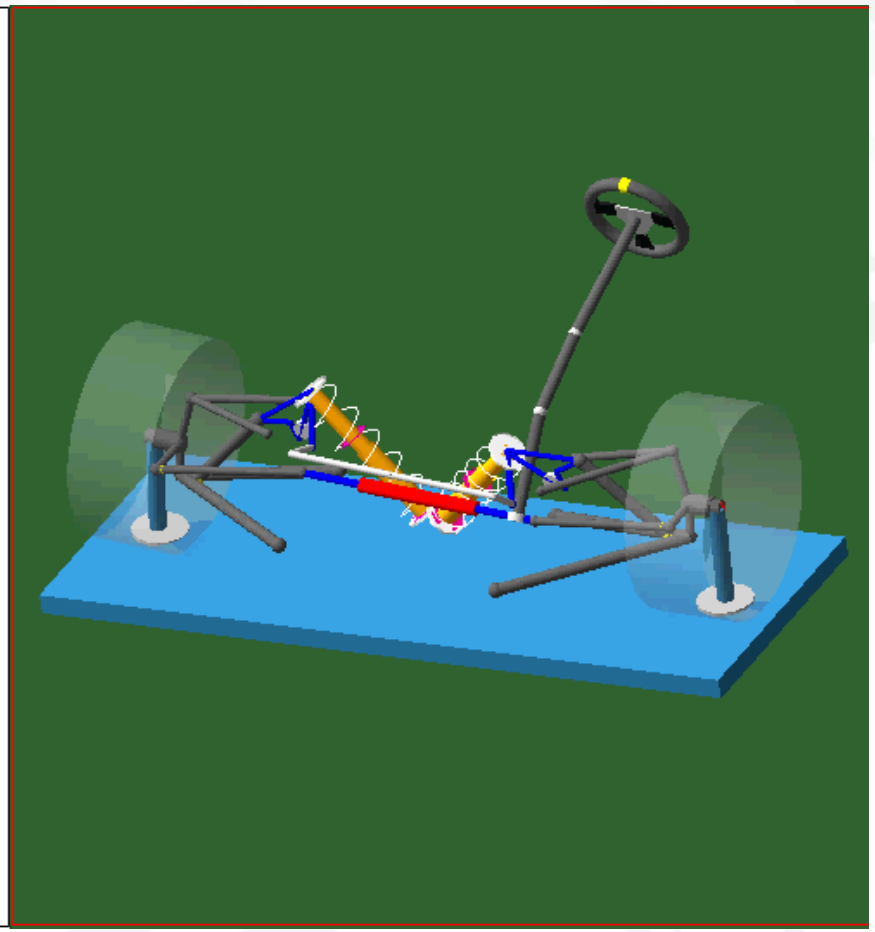
Kinematic Analysis

- **ADAMS example: Front Roll Analysis**





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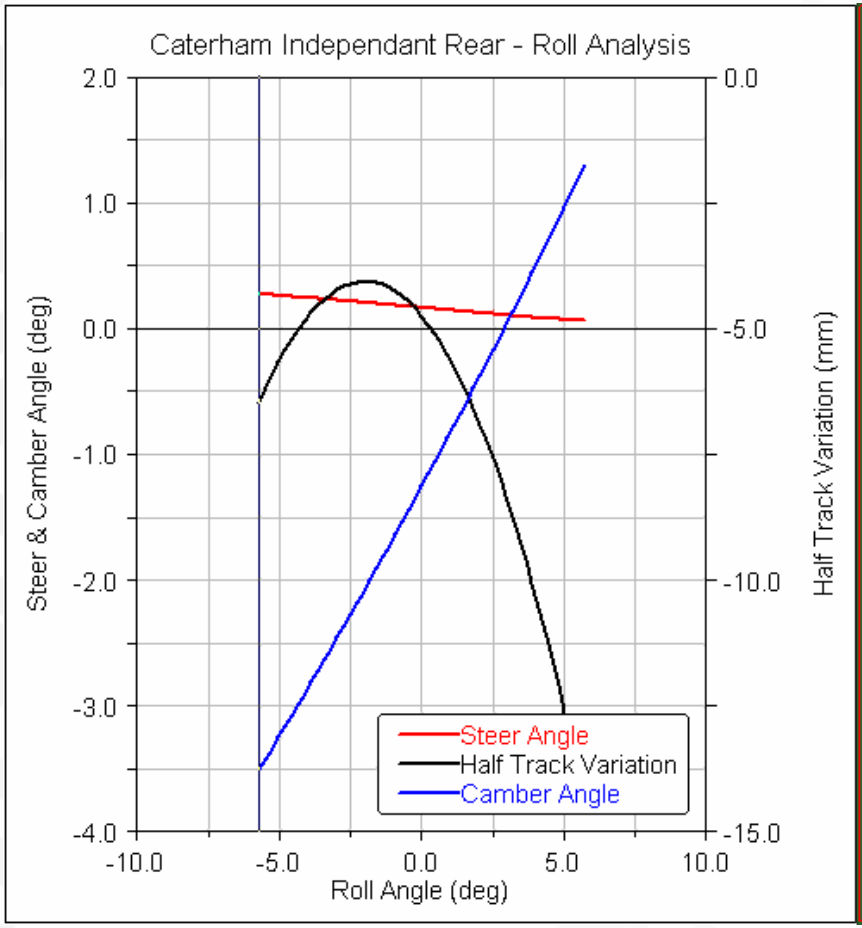
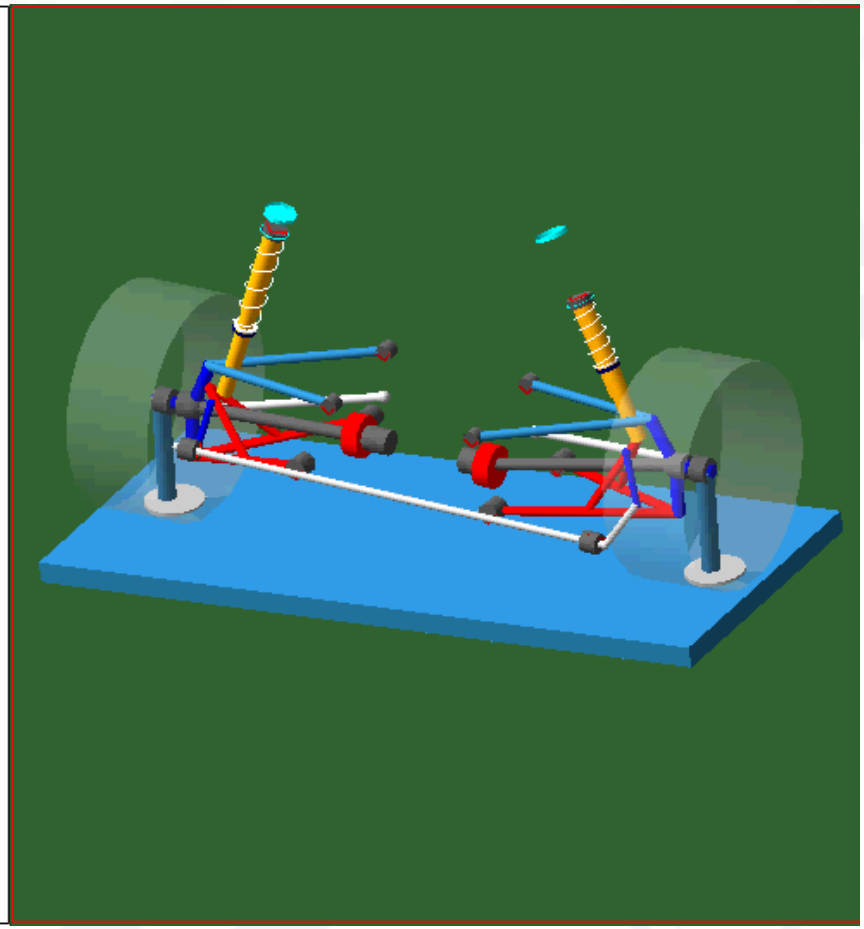
Kinematic Analysis

- **ADAMS example: Rear Roll Analysis**





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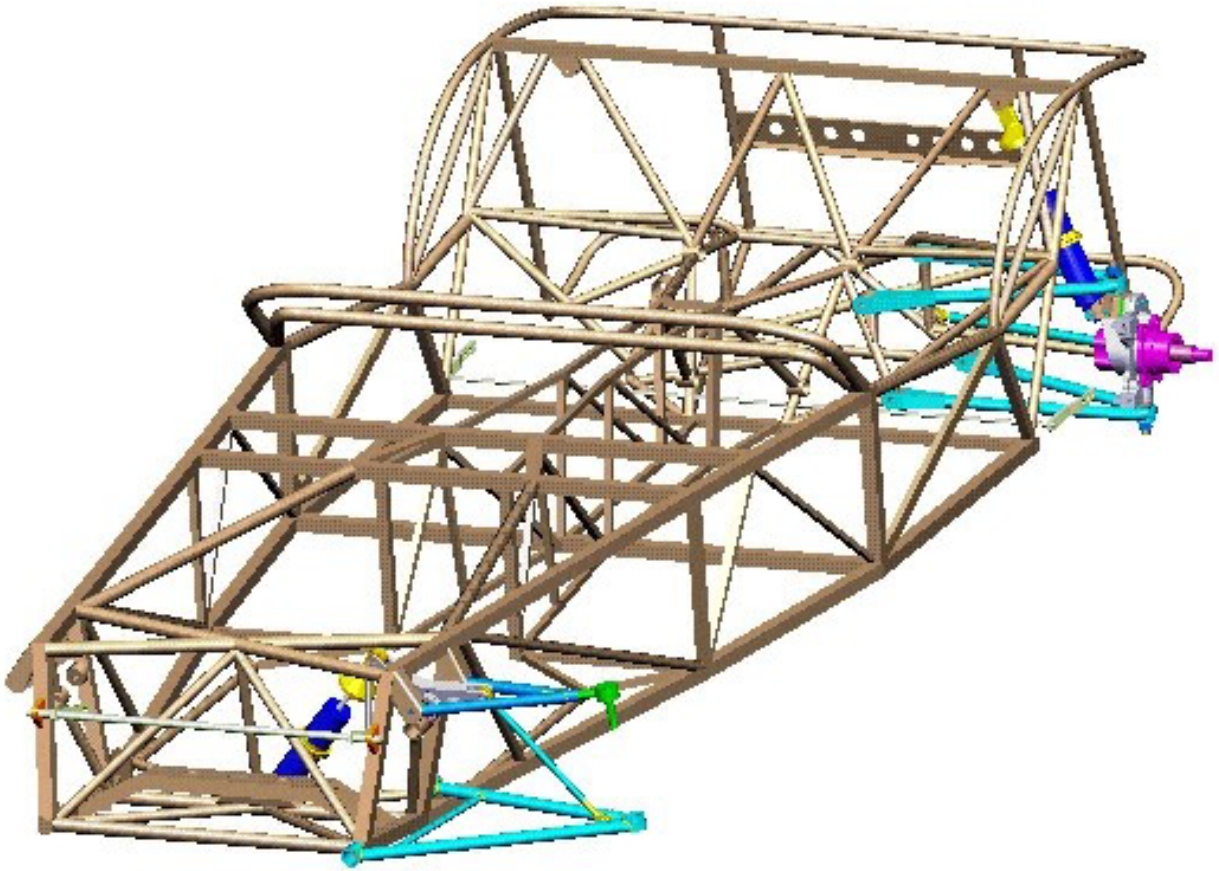
New Design Modeling

- **Full chassis and suspension 3D solid modeled in SDRC I-deas**



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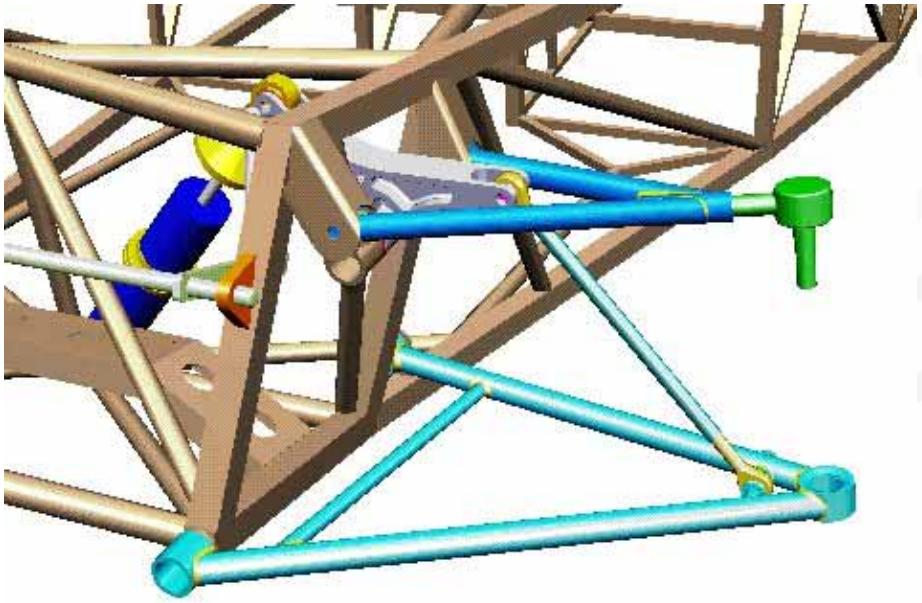
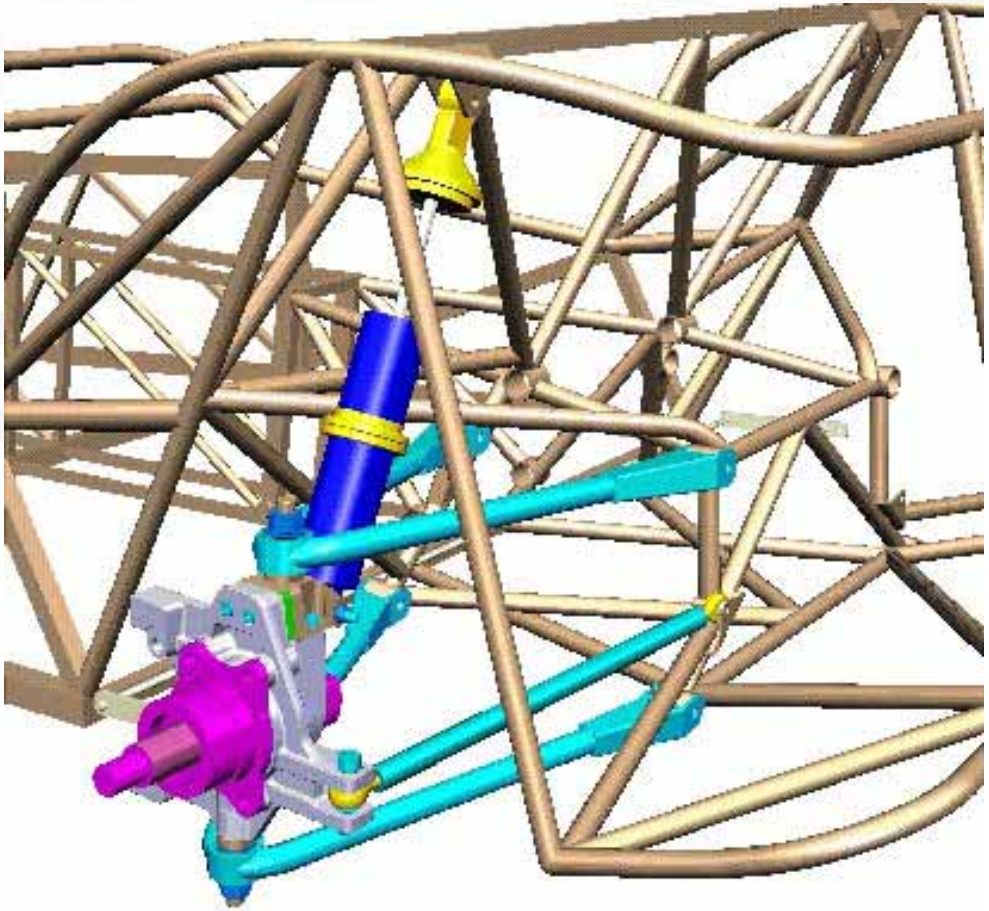
New Design Modeling

- Component design reviewed in partnership with Caterham and their suppliers





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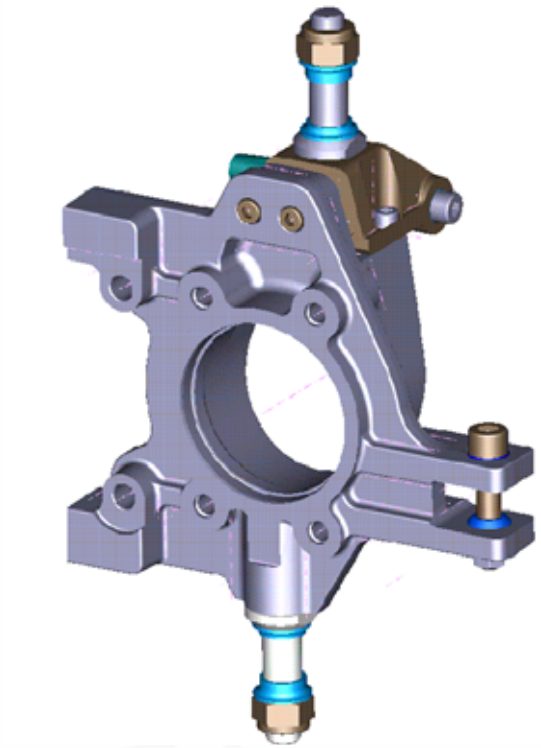
Component Design

- **Component designs created from 3D hardpoints**



  - **New rear cast upright**

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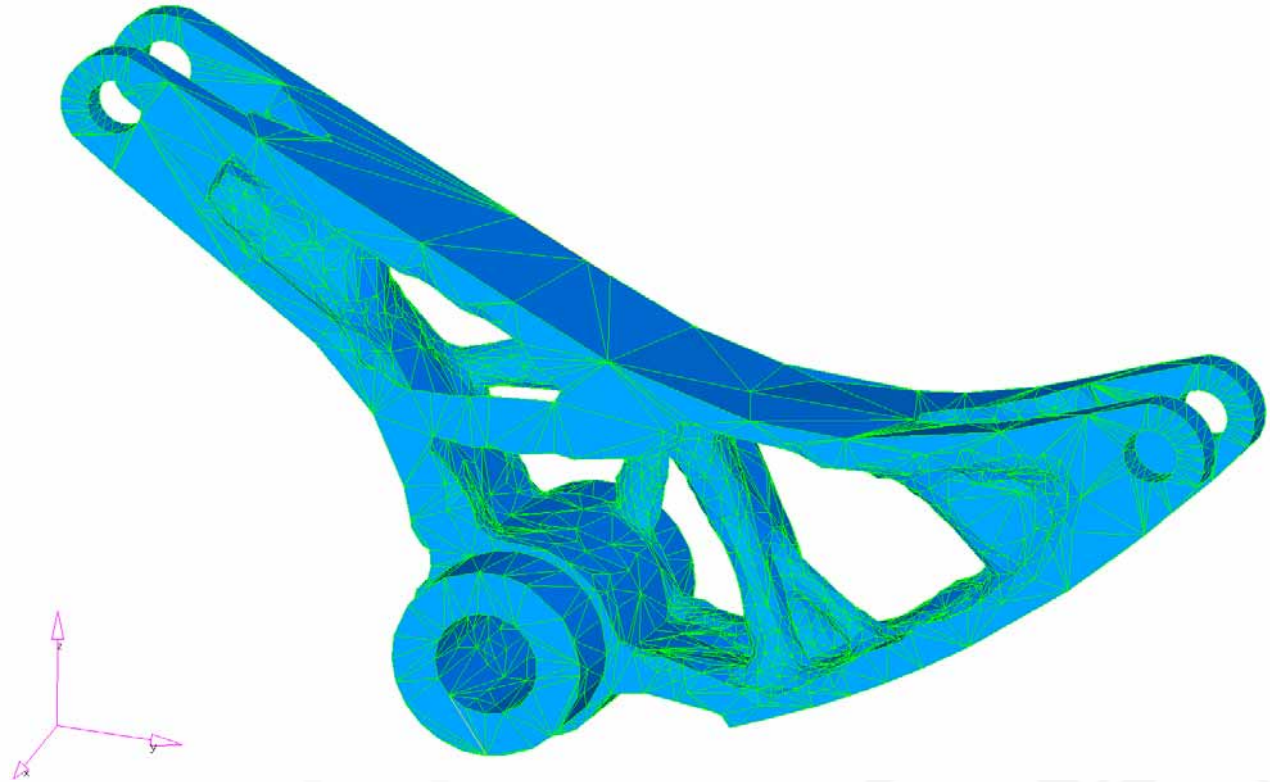
- **Component designs optimised using load cases generated from the ADAMS analysis**



- **Topology optimisation of the front rocker**

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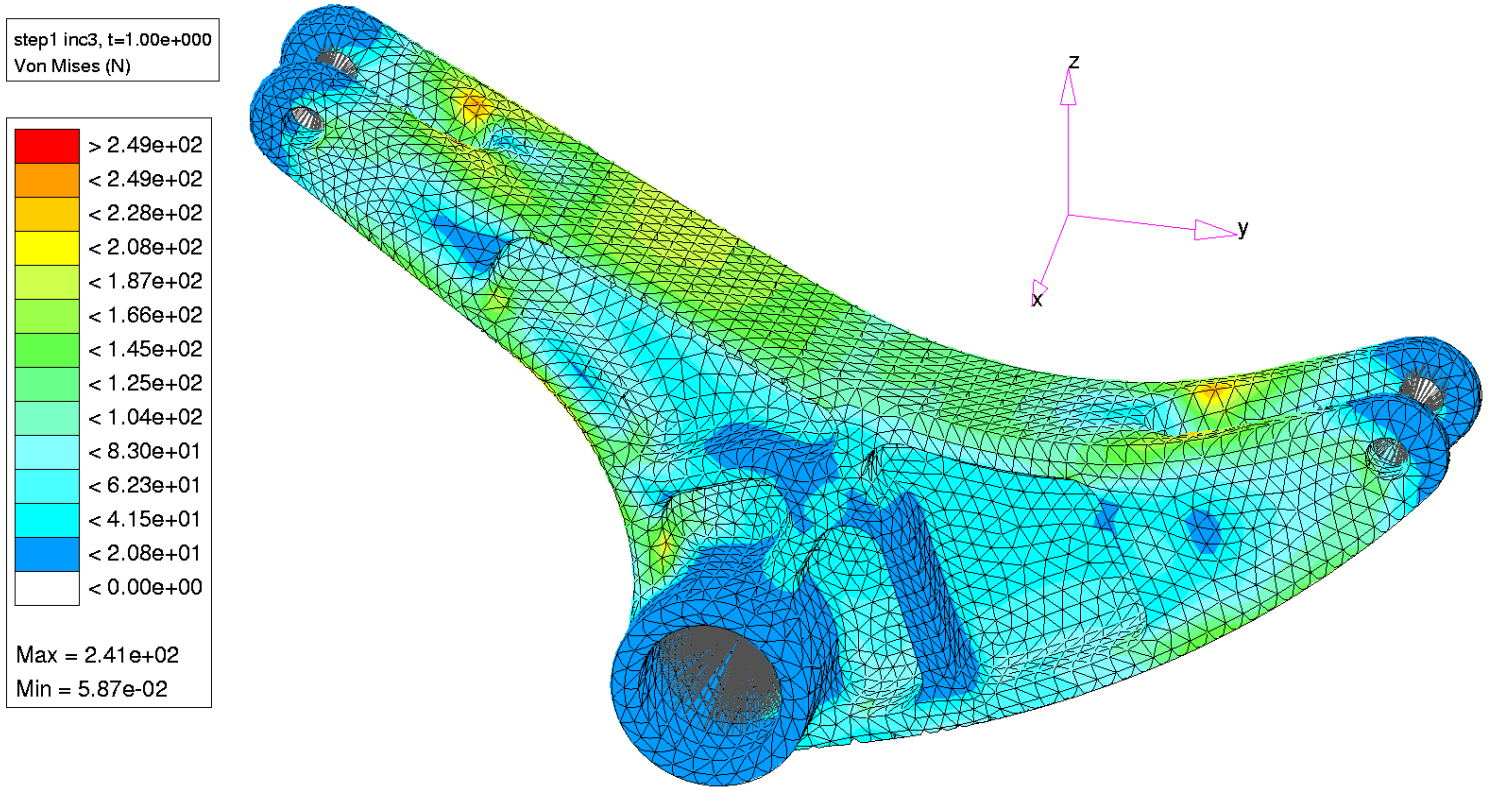
Component Design

- **Design verification using FEA on critical components**



- **ABAQUS stress analysis of the front rocker design under a 5g loadcase**

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Initial Set-Up Calculations

- **Initial suspension set-up calculation for spring and bar rates performed using Multimatic software**

MTC ride roll & damper v1.1 | Vehicle info : **Caterham SV Race** | Units: Metric

Input

Vehicle information	front	rear	units
Wheelbase	2298.0		mm
Track width	1510.0	1410.0	mm
CG height (from ground)	336.0		mm
Roll centre height (from ground)	21.0	61.0	mm
Total mass	285.0	326.0	kg
Unsprung mass (per corner)	35.0	35.0	kg
Loaded tyre radius	250.0	250.0	mm
Tyre vertical rate	200.0	200.0	N/mm
Bushing wind-up rate (at the wheel)	1.0	1.0	N/mm
Motion ratio (spring/wheel)	0.69	0.84	-

*need to add driver/passaget, fuel capacity/mass and location

Ride and Roll targets	front	rear	units
Ride natural frequency	2.11	2.33	Hz
Total vehicle roll gradient	1.33		deg/g
[5] Load transfer distribution (% front)	53.00		%
Maximum lateral acceleration	1.00		g
Anti-roll bar torsional length	537.0	990.0	mm
Lever arm length	110.0	130.0	mm
Motion ratio (pivot/wheel)	0.50	1.00	-
[5] Roll bar installation efficiency	80.0	80.0	%
Chassis installation stifness	2000	3000	Nm/deg
[4] Anit-roll bar section	solid	tube	
Anti-roll bar thickness (use solver)		1.2	mm

Output

Vehicle information	front	rear	units
Total vehicle mass	611.0		kg
% front mass	46.6	53.4	%
Sprung mass	471.0		kg
% sprung mass	45.6	54.4	%
(1) Sprung mass CG height from ground	361.6		mm
Total vehicle mass CG location	1226.1	1071.9	mm
Sprung mass CG location	1249.0	1049.0	mm

Ride	front	rear	units
Ride rate required	18.8	27.5	N/mm
Wheel centre rate	19.77	31.9	N/mm
Spring rate (metric)	**39.4**	**43.8**	N/mm
Spring rate (imperial - reference)	225.0	250.0	lbs/in

Roll	front	rear	units
Rolling moment lever arm	318.77		mm
Rolling moment	1472.90		Nm/g
Tyre roll gradient	0.27		deg/g
Sprung mass roll gradient	1.06		deg/g
Total roll rate required	1393.03		Nm/deg
Total load transfer	1379.42		N/g
Load transfer	731.09	648.33	N/g
(1) Roll rate required	839.83	557.32	Nm/deg
Roll rate - no bar (at wheel center)	393.36	553.57	Nm/deg
(2) Anti-roll bar roll rate	1054.42	130.91	Nm/deg
Anti-roll bar contribution	125.55	23.49	%
bar at the lever arm pivot rate	22.38	1.11	Nm/deg
(2-3) Anti-roll bar diameter-*solid*	**18.0**		mm
(2-3) Anti-roll bar diameter-*tube* SOLVE		**11.1**	mm
(3) Anti-roll bar shear stress	0.21	0.11	Mpa

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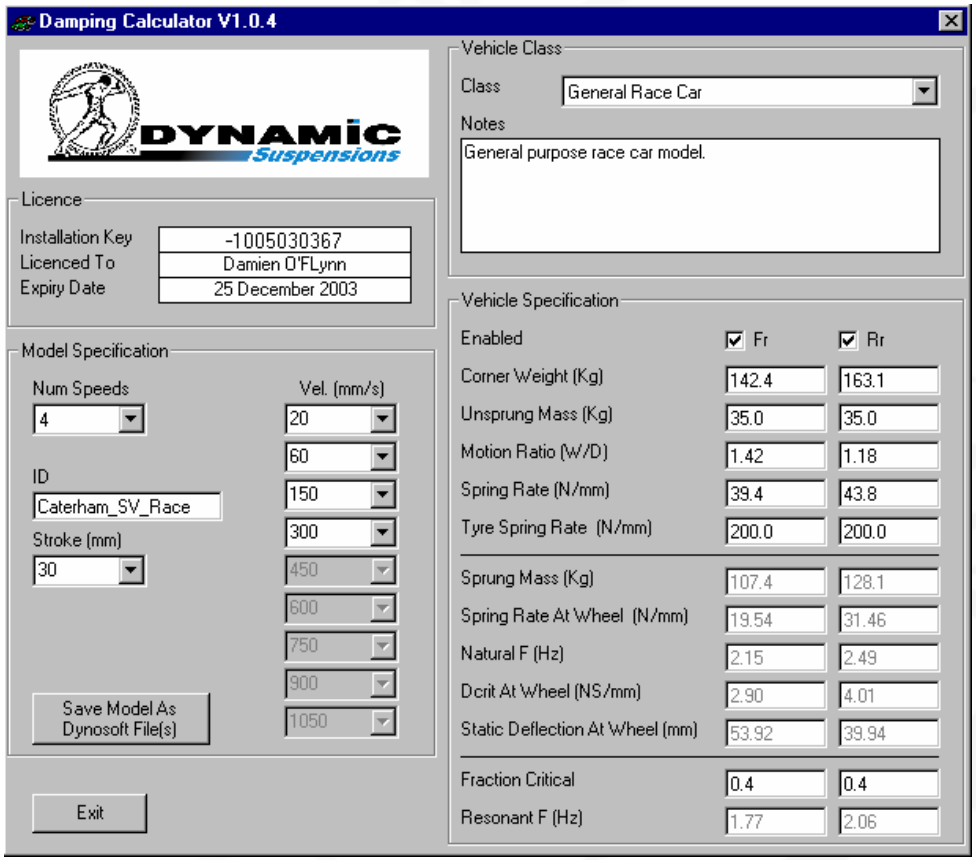
Initial Set-Up Calculations

- **Initial damper forces calculated using Multimatic Dynosoft software**



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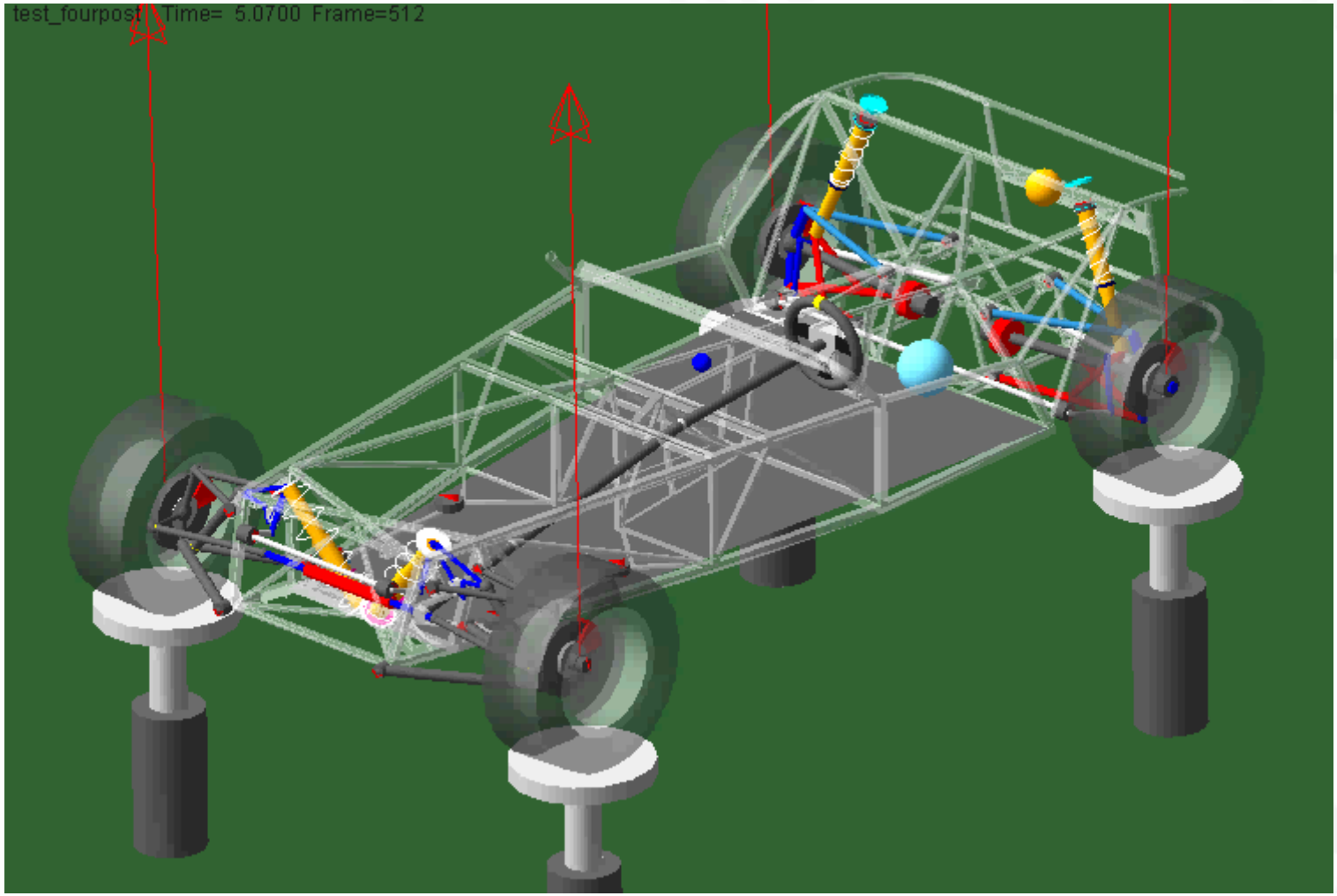
Dynamic Analysis

- **Virtual 4-Post Rig Analysis**



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Prototype Assembly

- **Build support at Caterham's Dartford, UK factory**

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K+C Rig Test

- Suspension kinematics and compliances measured on single axle K+C rig and compared with ADAMS analysis

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4-Post Rig Test

- **Vehicle tuned on MTCE 4-post rig in Thetford, UK using Dave Williams methodologies**

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Road Testing

- **Initial road testing at Millbrook conducted by Murray White, Head of Vehicle Development:**

“Very Impressive performance out of the box; greatly reduced steering effort, kickback, and rear-end steer over bumps.”

“Limit balance was progressive and adjustable and proved sensitive to anti-roll bar stiffness changes.”

“The yaw center seems about right for a good compromise between agility and stability.”

“Good phasing of the front to rear axle lateral force build up.”

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Track Testing

- **On-track development run and supported by MTCE staff: engineers, technicians and driver**

Snetterton Test: 13th September 2003. Driver: Scot Maxwell

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Track Testing

- On-track development run and supported by MTCE staff: engineers, technicians and driver

“The new suspension makes the vehicle more stable and easier to drive faster.” – Scott Maxwell, Driver

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Results

- **Program results:**
  - **Project managed and delivered on time to Caterham**
  - **Incorporated increased level of adjustability**
  - **6 kg reduction in unsprung mass**
  - **Improved kinematics:**
    - **lower roll centre both front and rear**
    - **significant reduction in hub and ground offset**
    - **Improved wheel recession and front/rear anti-dive/ anti-lift balance**
  - **Ride and handling: the car was very good “right out of the box”. The steering feel and response was improved and the handling was well balanced, progressive and adjustable.**

- **Conclusions:**
  - **Successful integration of target setting, analysis, rig testing and road testing**
  - **Front and Rear suspension systems designed to complement each other**
  - **Modern platform for Caterham future derivatives**