9

Truck Arm
Rear Suspension Kinematics
(*It's just not this simple!)*

Important Note: Many of the examples in this chapter, for the sake of clarity, are shown in single plane format which may not always represent the realities of three dimensional co-ordinate analysis. Points that intersect on a single plane do not **necessarily** intersect in three dimensional space. That is why the use of a three dimensional kinematics program such as WinGeo3 is so important.

Truck arm theory is much the same as that of the three link system except that the truck arms are solidly affixed to the bottom of the rear axle, bypassing the need for an upper link. In this way, the truck arm acts like a torque arm as the arms are torqued upward under acceleration. Unlike a torque arm, but like the three link system, it does not decouple when being torqued down under braking.

The primary drawbacks of the truck arm system are that it is heavy, bulky and not very elegant and the primary advantage is that the system is very stable (produces small kinematic changes over a wide range of suspension iterations). For fast wide radius corners combined with a very heavy chassis, the truck arm system works rather well. This is not a highly sophisticated system that responds to subtle changes, but, within limits, it is tunable. Design changes and construction techniques over the past few years have dramatically improved the arm's response to spring, damper and bar changes.

The truck arm beams are solidly affixed to the rear axles with U bolts - Figures 9-1 & 9-4. They are mounted to the frame with either rubber bushings with steel inserts or spherical bearings - Figures 9-2 & 9-3. Stock car teams refer to the spherical bearings as mono balls.

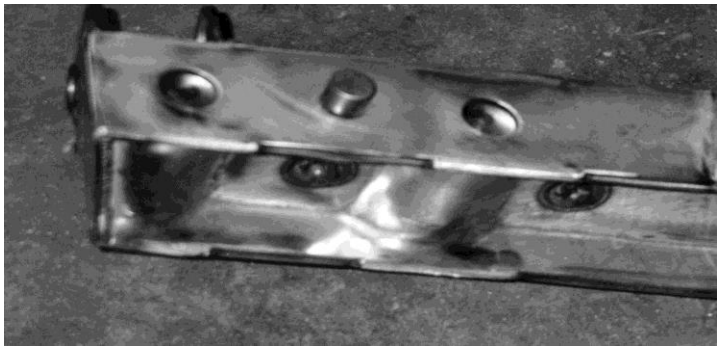


Figure 9-1



Figure 9-2

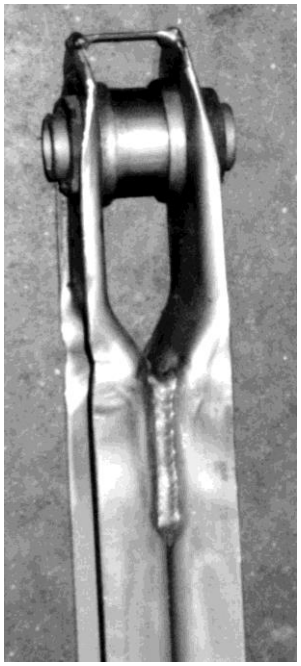


Figure 9-3

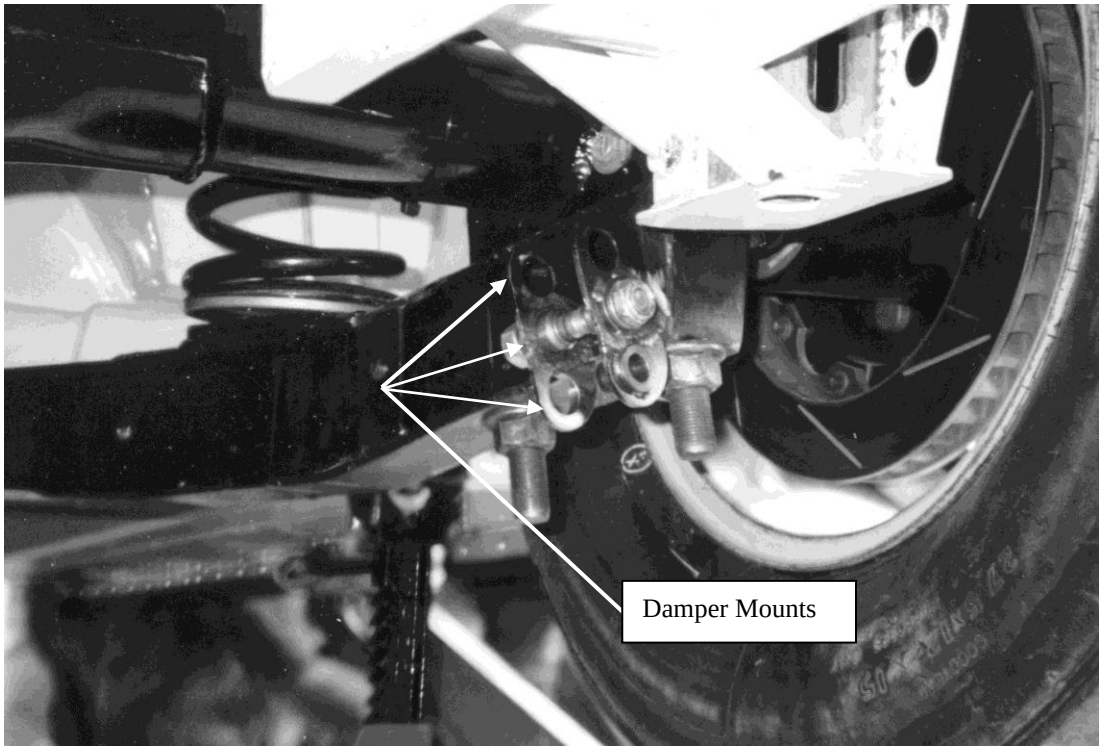


Figure 9-4

The truck arm is in the form of a beam which is strong in compression and beaming but relatively weak in twisting (torsion/axial torque) - Figure 9-5. The bottom and top of the beam is heavily reinforced at the back where it kicks up - this is also where the spring perch is attached - Figure 9-6 & 9-7. Notice the three damper mounting positions in Figure 9-4. When the rubber and steel front bushings are used, the bushings do not have sufficient axial rotation to allow for a full range of suspension motion. In this case, the beam/truck arm needs to axially torque or twist. The forces transmitted through the truck arm when using the steel and rubber bushings is quite unpredictable. The use of spherical bearings/mono balls considerably reduces the need for the beam to twist. On the other hand, the rubber bushings do lessen acceleration and braking torque shock, which, in turn, helps prevent wheel hop and sheared loss of contact patch grip. It is for this reason that teams still use the rubber bushings at selected tracks.

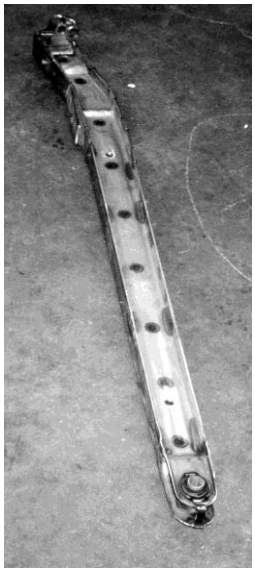


Figure 9-5

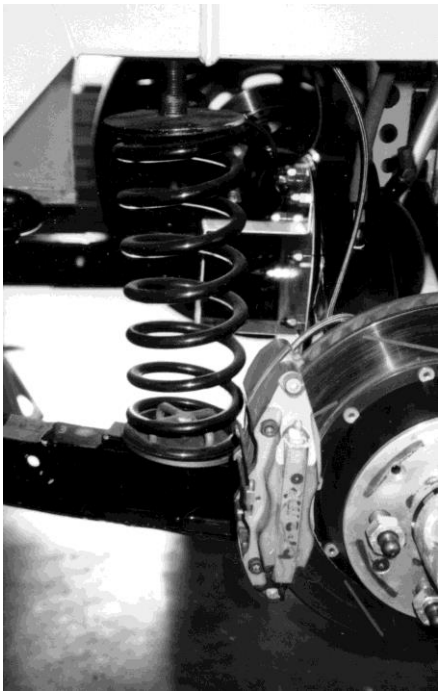


Figure 9-6

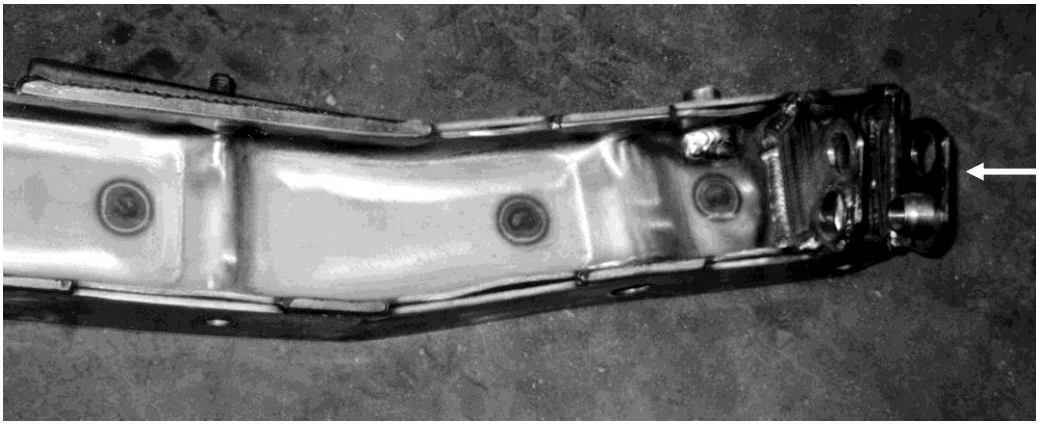


Figure 9-7

Figure 9-8 shows a truck arm model that allows the user to experiment with truck arm kinematics. The rear mounts are solidly affixed to the axle while the front mounts allow for axial rotation. The frame mounts are welded to the table.



Figure 9-8

Longitudinal repositioning of the axle housing is accomplished by the use of slotted right side front mounts in conjunction with an eccentric washer - Figures 9-9. This longitudinal repositioning allows the team to move the right side of the axle housing back and forth, which, in turn, allows for the centering of the axle housing perpendicular to the chassis longitudinal center line, or conversely, to offset the axle housing, thereby producing rear steer. As previously stated, one advantage of the truck arm link over the three link system is that once the axle is set, it moves back and forth much less during the various suspension motion iterations as shown in Tables 9-1 / 9-8. The vertical mounting positions of the arms below the axle and at the frame, Figure 9-10, follows the same theory as the three link system - Chapter 8.

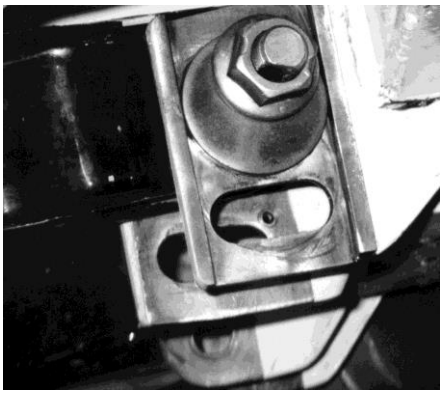


Figure 9-9

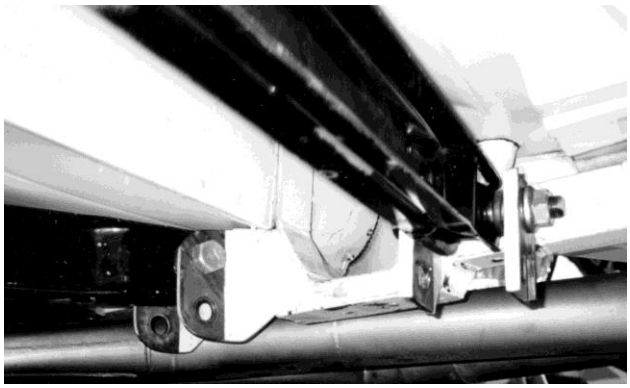


Figure 9-10

When the truck arms are moved up or down at the front frame mounts, pinion angle shims often need to be added between the truck arm and the axle mounts to maintain the correct pinion angle. Table 9-1 illustrates pinion angle changes as the result of six different datum roll center positions. Remember the datum roll center is in a constant state of flux. Changes in the datum roll center position is the primary factor in all kinematic variance when using the truck arm system (excluding track bar angle changes). Notice all steer examples in Tables 9-1 through 9-5 are towards the understeer side.

Table 9-1

Live Axle Truck Arm Suspension											
Bump L = 0.50			Ride = -0.250			L Base Clearance/ride height = 5.00					
Bump R = -1.00			Roll = 1.433			R Base Clearance/ride height = 5.00					
Y offset	Z offset	L Clear.	R Clear.	L spring	R Spring	Scrub	Steer	L Load	R Load	Y Change	Z Change
0.00	0.00	5.498	3.998	0.205	-0.618	0.247	0.093	-50.156	151.273	0.000	0.000
20.00	0.00	5.998	4.498	0.613	-0.210	0.246	0.087	-149.796	51.439	0.003	-0.349
-20.00	0.00	4.998	3.498	-0.203	-1.026	0.254	0.104	49.753	251.320	-0.003	0.349
0.00	14.00	5.503	4.003	0.209	-0.615	-0.103	0.093	-51.029	150.398	0.244	0.002
20.00	14.00	6.003	4.503	0.616	-0.207	-0.104	0.087	-150.666	50.566	0.247	-0.347
-20.00	14.00	5.003	3.503	-0.200	-1.023	-0.096	0.104	48.877	250.444	0.2	0.4

Table 9-2 shows kinematic changes as the result of 3 degrees of chassis roll in combination with various truck arm frame mounting positions (Fr = frame mount – Ax = axle mount). Notice how stable the scrub and spring numbers are through the entire range of iterations. The truck arm system sees considerably less scrub than the three link system during similar ride, roll and bump iterations. Steer shows some variance but not as much as seen with the three link system.

Table 9-2

Live Axle Truck Arm Suspension											
Bump L = 0.00		Ride = -0.00		L Base Clearance = 5.00			Y Rotation Point = 10.00				
Bump R = -0.00		Roll = 3		R Base Clearance = 5.00			Z Rotation Point = 1.00				
L Lower	R Lower	L Clear.	R Clear.	L spring	R Spring	Scrub	Steer	L Load	R Load	Y Change	Z Change
Fr/Ax	Fr/Ax										
6.5/11.25	6.5/11.25	7.088	3.948	1.278	-0.445	0.452	0.172	-312.137	108.786	-0.039	0.525
8.5/11.25	8.5/11.25	7.088	3.948	1.277	-0.446	0.462	0.088	-311.909	109.004	-0.039	0.525
6.5/11.25	8.5/11.25	7.088	3.948	1.278	-0.445	0.454	0.151	-312.170	108.845	-0.039	0.525
8.5/11.25	6.5/11.25	7.088	3.948	1.277	-0.446	0.460	0.109	-311.878	108.949	-0.039	0.525

Table 9-3 uses the same frame mount iterations as Table 9-2 but with left bump at 1" and right bump at -2". Once again, we see how stable the truck arm system is.

Table 9-3

Live Axle Truck Arm Suspension											
Bump L = 1.00		Ride = -0.500		L Base Clearance = 5.00			Y Rotation Point = 10.00				
Bump R = -2.00		Roll = 2.866		R Base Clearance = 5.00			Z Rotation Point = 1.00				
L Lower	R Lower	L Clear.	R Clear.	L spring	R Spring	Scrub	Steer	L Load	R Load	Y Change	Z Change
Fr/Ax	Fr/Ax										
6.5/11.25	6.5/11.25	6.495	3.495	0.814	-0.832	0.441	0.175	-199.015	203.644	0.041	-0.348
8.5/11.25	8.5/11.25	6.495	3.495	0.813	-0.833	0.451	0.094	-198.829	203.904	0.041	-0.348
6.5/11.25	8.5/11.25	6.495	3.495	0.813	-0.833	0.446	0.134	-199.016	203.912	0.041	-0.348
8.5/11.25	6.5/11.25	6.495	3.495	0.813	-0.833	0.447	0.135	-198.828	203.639	0.041	-0.348

Table 9-4 illustrates a number of ride and pitch iterations. As in all previous examples, spring, scrub and steer are very stable.

Table 9-4

Live Axle Truck Arm Suspension											
Y Rotation Point = 10.00				L Base Clearance = 5.00							
Z Rotation Point = 1.00				R Base Clearance = 5.00							
		L Lower	R Lower	L Clear.	R Clear.	L spring	R Spring	Scrub	Steer	L Load	R Load
Ride	Pitch	Fr/Ax	Fr/Ax								
-2	0	6.5/11.25	6.5/11.25	3.000	3.000	-1.6	-1.6	0.058	0.035	399.9	399.5
2	0	6.5/11.25	6.5/11.25	7.000	7.000	1.6	1.6	0.046	0.038	-397.5	-397.5
-2	2	6.5/11.25	6.5/11.25	2.998	2.998	-1.6	-1.6	0.057	0.041	398.4	397.4
2	2	6.5/11.25	6.5/11.25	6.998	6.998	1.6	1.6	0.045	0.043	-393.6	-394.1
-2	-2	6.5/11.25	6.5/11.25	2.998	2.998	-1.6	-1.6	0.059	0.030	405.7	405.7
2	-2	6.5/11.25	6.5/11.25	6.998	6.998	1.6	1.6	0.047	0.032	-399.267	-398.713

Tables 9-5 & 9-6 show changes as the result of various track bar mounting positions in conjunction with roll and ride. Changing the track bar angle influences scrub considerably more than any variance in truck arm geometry. Notice that angling the track bar either up or down, under ride conditions, results in the axle steer attitude moving from a slight understeer condition to a slight oversteer condition - Table (6).

Table 9-5

Live Axle Truck Arm Suspension											
					L Base Clearance = 5.00				Y Rotation Point = 10.00		
		L Lower	R Lower		R Base Clearance = 5.00				Z Rotation Point = 1.00		
Roll	Bar Ax/Fr	Fr/Ax	Fr/Ax	L Clear.	R Clear.	L spring	R Spring	Scrub	Steer	L Load	R Load
3.00	12/12	6.5/11.25	6.5/11.25	7.088	3.948	1.275	-0.448	0.536	0.232	-311.564	109.580
3.00	12/8	6.5/11.25	6.5/11.25	7.088	3.948	1.280	-0.442	0.386	0.126	-314.139	108.636
3.00	8/12	6.5/11.25	6.5/11.25	7.088	3.948	1.276	-0.447	0.494	0.202	-310.677	108.729

Table 9-6

Live Axle Truck Arm Suspension					
Y Rotation Point = 10.00		Z Rotation Point = 1.00			
Ride	Bar Ax/Fr	Fr/Ax	Fr/Ax	Scrub	Steer
-2.00	12/12	6.5/11.25	6.5/11.25	0.057	0.035
-2.00	12/8	6.5/11.25	6.5/11.25	-0.134	-0.100
-2.00	8/12	6.5/11.25	6.5/11.25	-0.134	-0.100

Tables 9-7 & 9-8 illustrate changes in pinion angle as the result of various left/right wheel motion iterations. Table 9-7 uses a lower front truck arm mount while Table 9-8 uses a higher mounting position.

Table 9-7

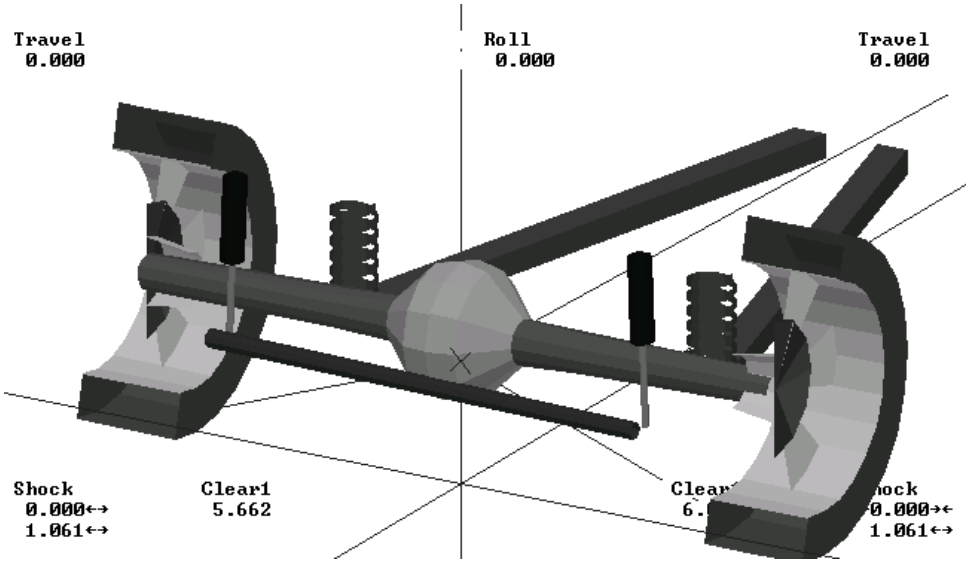
Live Axle Truck Arm Suspension												
Y Rotation Point = 10.00			Z Rotation Point = 1.00									
Left wheel	Right wheel	Roll	L Lower Fr/Ax	R Lower Fr/Ax	Pinion change	Left wheel	Right wheel	Roll	L Lower Fr/Ax	R Lower Fr/Ax	Pinion change
-1.0	-1.0	0.0	6.5/11.25	6.5/11.25	-0.882	-1.0	-1.0	0.0	8.5/11.25	8.5/11.25	-0.882
-2.0	-2.0	0.0	6.5/11.25	6.5/11.25	-1.766	-2.0	-2.0	0.0	8.5/11.25	8.5/11.25	-1.766
1.0	1.0	0.0	6.5/11.25	6.5/11.25	0.881	1.0	1.0	0.0	8.5/11.25	8.5/11.25	0.881
2.0	2.0	0.0	6.5/11.25	6.5/11.25	1.760	2.0	2.0	0.0	8.5/11.25	8.5/11.25	1.761
1.0	-1.0	1.9	6.5/11.25	6.5/11.25	-0.121	1.0	-1.0	1.9	8.5/11.25	8.5/11.25	-0.122
1.0	-2.0	2.9	6.5/11.25	6.5/11.25	-0.625	1.0	-2.0	2.9	8.5/11.25	8.5/11.25	-0.627
2.0	-0.5	2.4	6.5/11.25	6.5/11.25	0.509	2.0	-0.5	2.4	8.5/11.25	8.5/11.25	0.507

Table 9-8

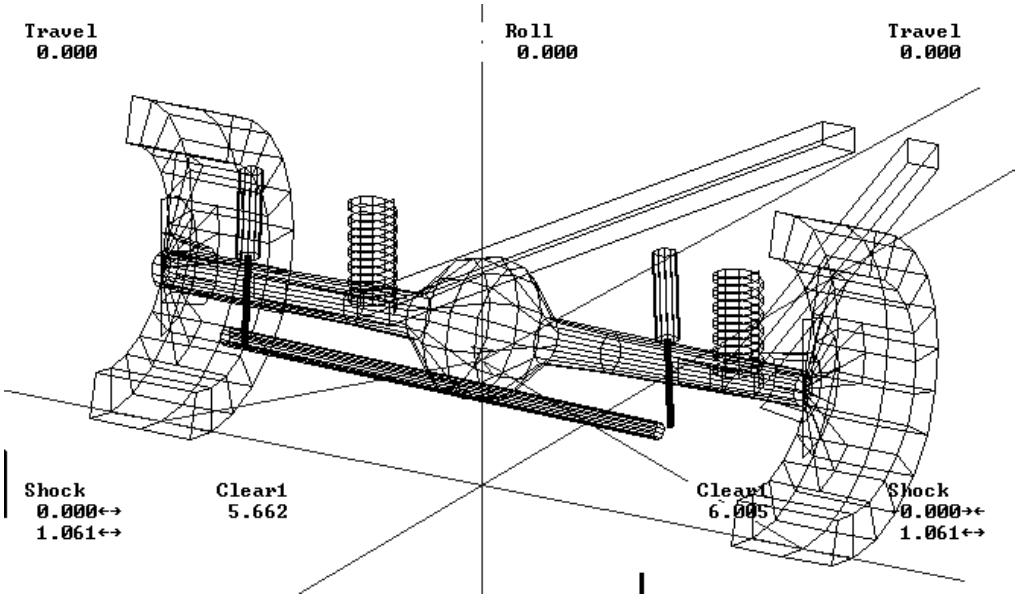
As previously discussed, understanding how a car's suspension system kinematics work is best accomplished through the use of software such as WinGeo3, providing the co-ordinates have been accurately measured and correctly entered into the program. A team would never have time to run through the number of kinematic scenarios needed to understand how a system works by testing them on a full size chassis. However, it is still important to confirm the computer's findings with a number of in-shop chassis tests. This task can be extremely daunting and difficult to accurately accomplish and if extreme accuracy isn't maintained, the results are worse than useless. The procedures involved in this type of testing are the domain of Book Two.

** Begin WinGeo3 Example(s)**

Win 9-1 and Win 9-2 show two views of the truck arm suspension system.



Win 9-1



Win 9-2

Win 9-3 shows the change in rear steer and hub motion through the phase rear *Path file* while Win 9-4 uses the same *Path file* but with both front truck arm mounts raised 1".

Hub and Steer Change

	Ride	Roll	Steer L	Hub X L	Hub Y L	Hub Z L	Hub X R	Hub Y R	Hub Z R
B=1.00g T=0.00g 1	-0.56	0.036	-0.01	-0.032	-30.239	13.36	-0.048	30.261	13.853
B=1.25g T=0.50g 2	-0.43	1.24	-0.052	-0.001	-30.015	13.36	-0.06	30.485	13.853
B=0.60g T=1.00g 3	-0.845	2.503	-0.115	0.001	-29.767	13.36	-0.129	30.733	13.853
B=0.15g T=1.25g 4	-1.136	3.128	-0.155	-0.002	-29.635	13.361	-0.176	30.865	13.853
B=0.05g T=1.53g 5	-1.207	3.817	-0.187	0.007	-29.503	13.361	-0.201	30.997	13.853
A=0.00g T=1.37g 6	-1.232	3.429	-0.173	-0.001	-29.573	13.361	-0.195	30.926	13.853
A=0.30g T=1.00g 7	-1.403	2.543	-0.148	-0.027	-29.73	13.361	-0.195	30.77	13.853
A=0.40g T=0.70g 8	-1.453	1.817	-0.119	-0.046	-29.867	13.36	-0.184	30.633	13.853
A=0.65g T=0.50g 9	-1.597	1.344	-0.105	-0.065	-29.951	13.36	-0.19	30.549	13.853
A=0.85g T=0.00g 10	-1.697	0.137	-0.052	-0.102	-30.184	13.36	-0.17	30.316	13.853

Win 9-3

Hub and Steer Change - Forward truck arm mounts raised 1"

	Ride	Roll	Steer L	Hub X L	Hub Y L	Hub Z L	Hub X R	Hub Y R	Hub Z R
B=1.00g T=0.00g 1	-0.56	0.036	-0.011	-0.041	-30.239	13.36	-0.057	30.261	13.853
B=1.25g T=0.50g 2	-0.43	1.24	-0.07	0.002	-30.017	13.36	-0.076	30.483	13.853
B=0.60g T=1.00g 3	-0.845	2.503	-0.151	0.006	-29.77	13.36	-0.161	30.73	13.853
B=0.15g T=1.25g 4	-1.136	3.128	-0.2	0.004	-29.64	13.361	-0.218	30.86	13.853
B=0.05g T=1.53g 5	-1.207	3.817	-0.242	0.017	-29.508	13.361	-0.249	30.991	13.853
A=0.00g T=1.37g 6	-1.232	3.429	-0.223	0.006	-29.578	13.361	-0.24	30.921	13.853
A=0.30g T=1.00g 7	-1.403	2.543	-0.185	-0.03	-29.733	13.361	-0.237	30.766	13.853
A=0.40g T=0.70g 8	-1.453	1.817	-0.146	-0.054	-29.869	13.36	-0.22	30.631	13.853
A=0.65g T=0.50g 9	-1.597	1.344	-0.125	-0.08	-29.952	13.36	-0.225	30.548	13.853
A=0.85g T=0.00g 10	-1.697	0.137	-0.055	-0.127	-30.183	13.36	-0.198	30.317	13.853

Win 9-4

**** End WinGeo3 Example(s)****