VERUS ENGINEERING AERODYNAMIC VEHICLE SETUP GUIDE

PORSCHE 987 CAYMAN

OVERVIEW

CALCULATION INPUTS……..pg 3

DOWNFORCE WITH WING ANGLE……pg 4-5

DRAG WITH WING ANGLE……..pg 6-7

RIDE HEIGHT SENSITIVITY……pg 8

SETUP STARTING POINT……pg 9

UNDERSTEER ADJUSTMENT……pg 10

OVERSTEER ADJUSTMENT……pg 11

ADJUSTING FOR ELEVATION, TEMPERATURE, & HUMIDITY……pg 12

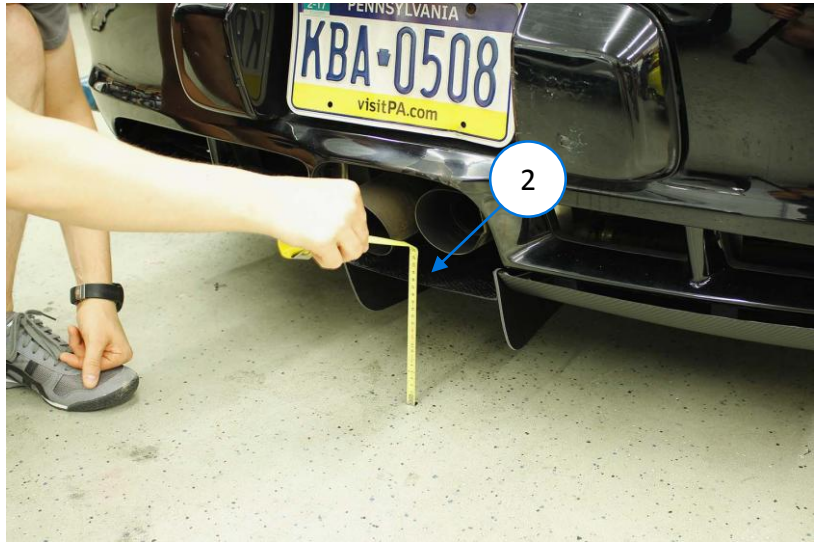
CALCULATION INPUTS

All calculations were completed at standard temperature and pressure. Downforce and drag numbers will change depending on elevation, temperature, and humidity. How to calculate these force changes with the elevation, temperature, and humidity will be discussed at the end of the setup sheet.

1. Front ride height is measured from the ground to the bottom side of the splitter.

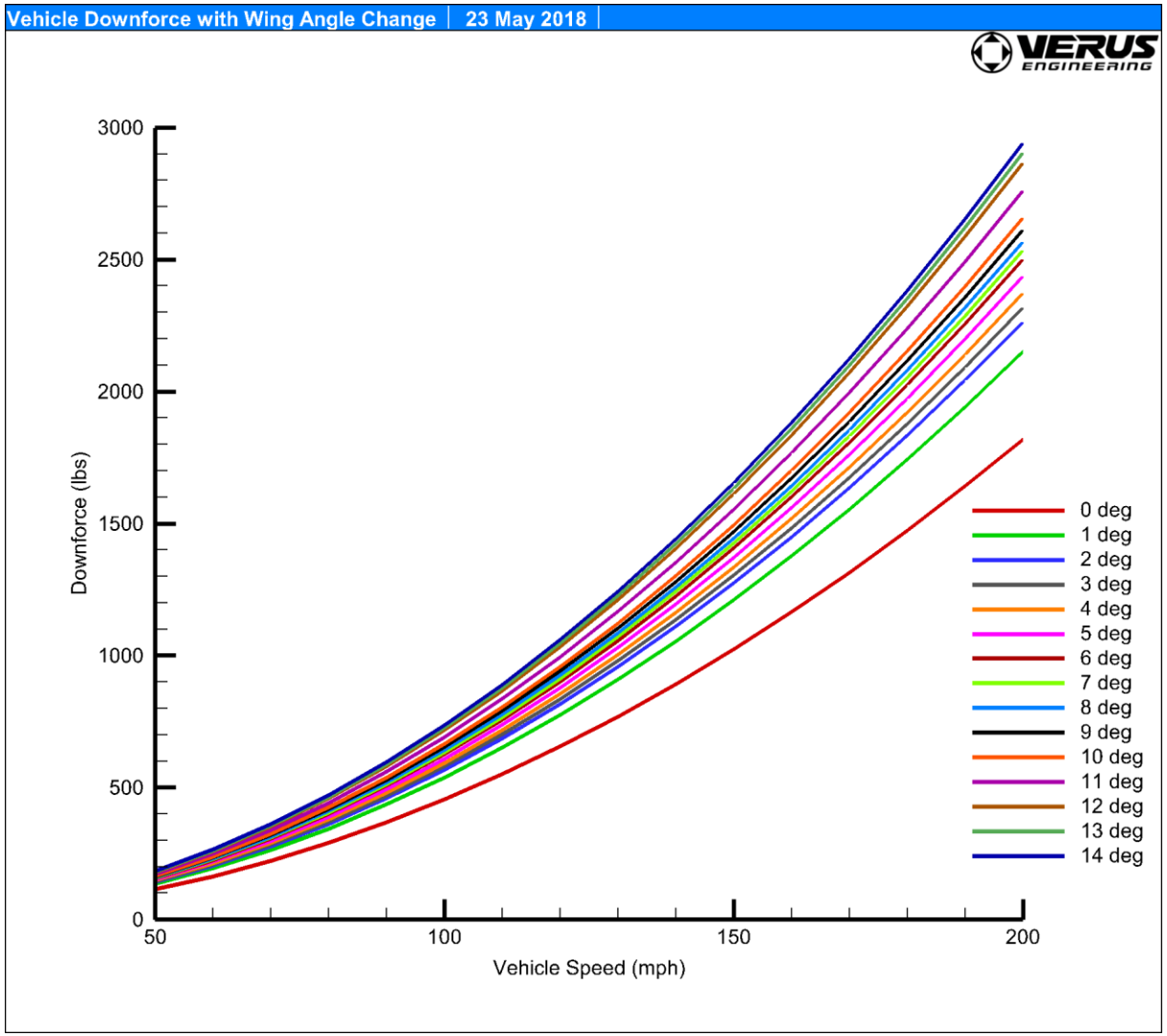
2. Rear ride height is measured from the ground to the bottom side of the rear edge of the diffuser

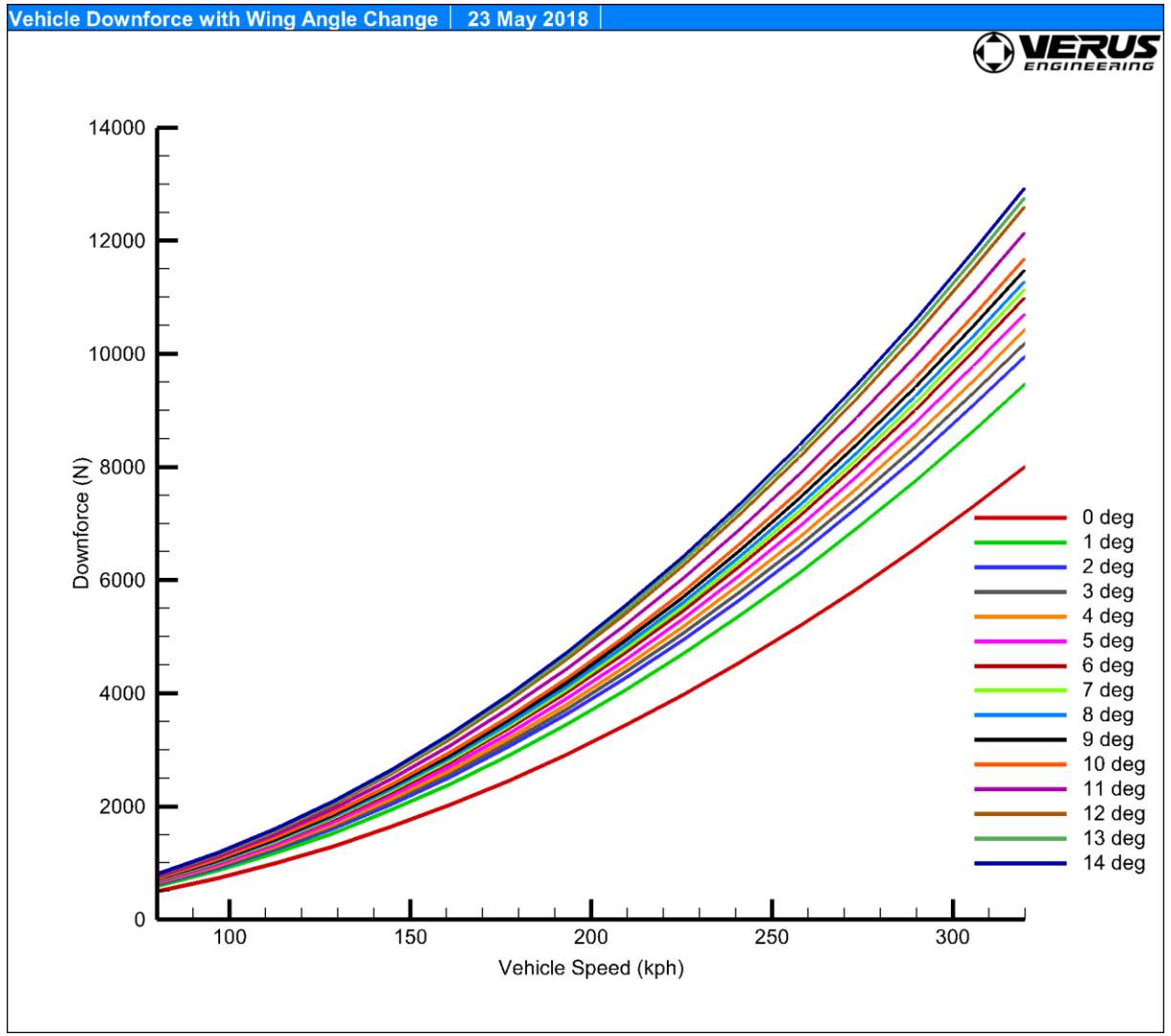
Note: A metric tape measure is recommended so conversions do not need to be made.



The data was also calculated at a standard ride height; 90mm FRH / 205mm RRH. Downforce and drag also change with ride height changes. Since the vehicle is constantly changing ride heights front and rear, a ride height sensitivity chart will also be displayed in this packet.

DOWNFORCE WITH WING ANGLE CHANGE





DOWNFORCE WITH WING ANGLE CHANGE

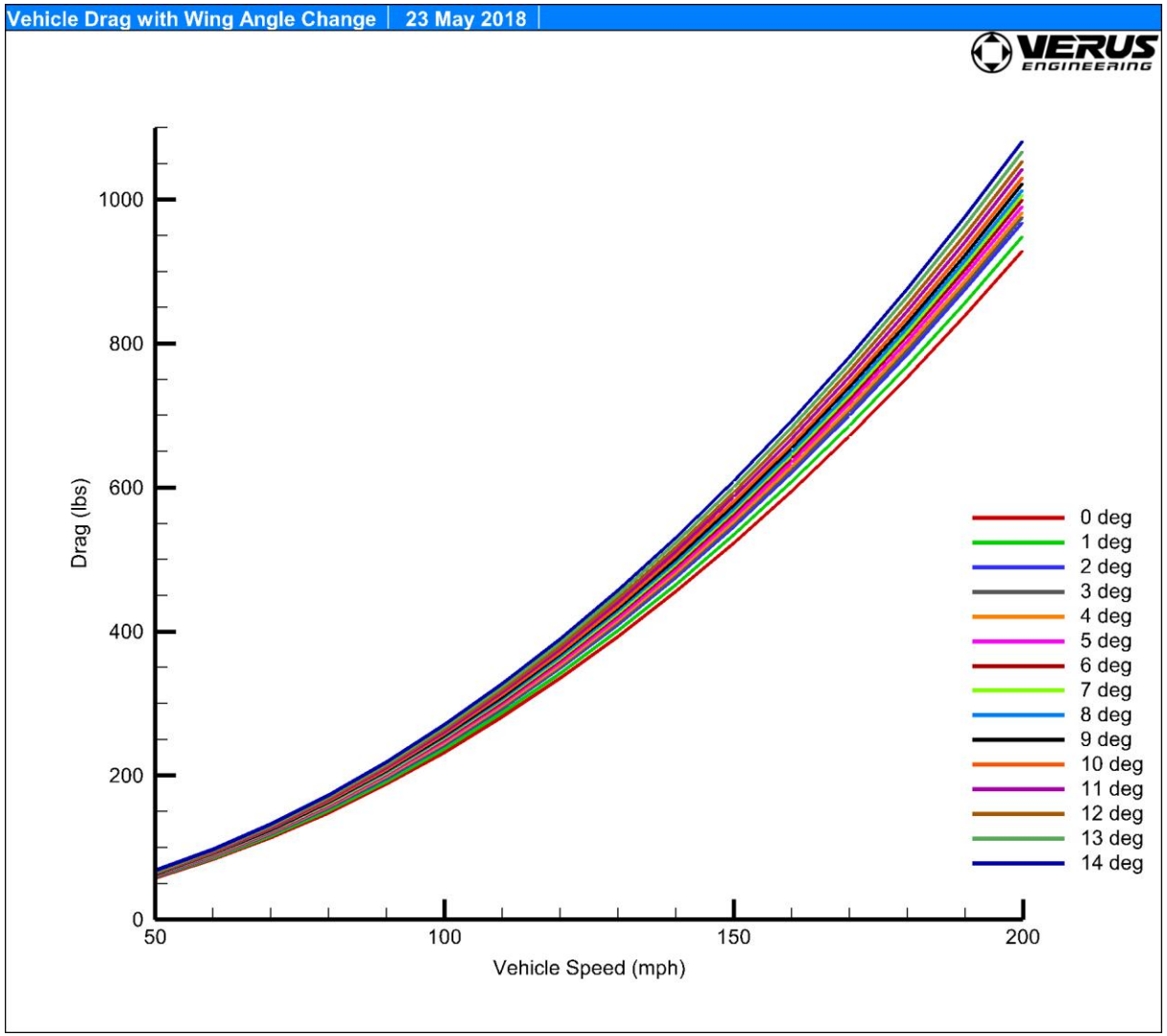
Velocity(mph)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
50	114	134	142	145	148	152	156	158	161	163	166	173	179	182	184
60	164	194	204	209	214	219	225	228	231	235	239	249	258	261	265
70	223	264	277	284	291	299	306	311	315	320	326	338	351	356	360
80	291	344	362	371	380	390	400	406	411	418	425	442	459	465	471
90	368	436	459	470	480	493	507	513	520	529	538	559	581	588	596
100	455	538	566	580	593	609	625	634	642	653	665	691	717	726	736
110	550	651	685	701	718	737	757	767	777	791	804	836	867	879	890
120	655	775	815	835	854	877	901	913	925	941	957	995	1032	1046	1059
130	769	909	957	980	1002	1030	1057	1071	1085	1104	1123	1167	1211	1227	1243
140	892	1054	1110	1136	1163	1194	1226	1242	1258	1281	1303	1354	1405	1423	1442
150	1024	1210	1274	1304	1335	1371	1407	1426	1445	1470	1495	1554	1613	1634	1655
160	1165	1377	1450	1484	1518	1560	1601	1622	1644	1673	1701	1768	1835	1859	1883
170	1315	1555	1636	1675	1714	1761	1807	1831	1856	1888	1921	1996	2072	2099	2126
180	1474	1743	1835	1878	1922	1974	2026	2053	2080	2117	2153	2238	2323	2353	2383
190	1642	1942	2044	2093	2141	2199	2258	2288	2318	2359	2399	2494	2588	2622	2656
200	1820	2152	2265	2319	2373	2437	2501	2535	2568	2613	2658	2763	2867	2905	2942

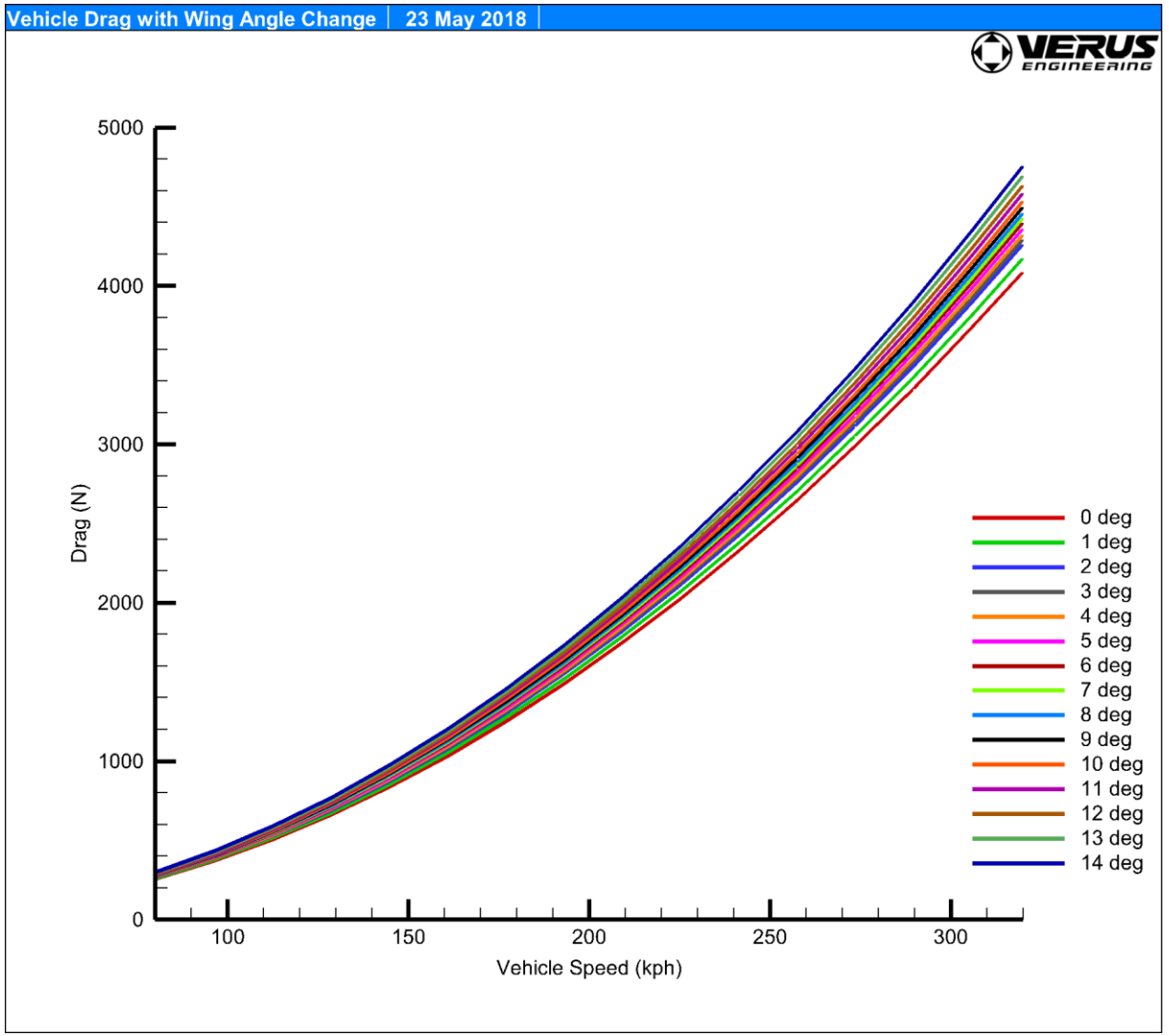
Forces in lbs

Velocity (kph)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
80	506	598	630	645	660	678	695	705	714	727	739	768	797	808	818
97	728	861	907	928	950	976	1001	1015	1028	1046	1064	1106	1148	1163	1178
113	992	1172	1234	1264	1293	1328	1363	1381	1400	1424	1449	1506	1562	1583	1603
129	1295	1531	1612	1650	1689	1734	1780	1804	1828	1860	1892	1966	2041	2067	2094
145	1639	1938	2040	2089	2137	2195	2253	2283	2313	2354	2395	2489	2583	2617	2650
161	2024	2393	2519	2579	2638	2710	2782	2819	2856	2906	2956	3072	3189	3230	3272
177	2448	2895	3048	3120	3193	3279	3366	3411	3456	3517	3577	3718	3858	3909	3959
193	2914	3446	3627	3713	3799	3903	4006	4059	4113	4185	4257	4424	4592	4652	4712
209	3420	4044	4257	4358	4459	4580	4701	4764	4827	4912	4996	5193	5389	5459	5530
225	3966	4690	4937	5054	5171	5312	5452	5525	5598	5696	5794	6022	6250	6332	6413
241	4553	5384	5667	5802	5936	6098	6259	6343	6426	6539	6652	6913	7174	7268	7362
257	5180	6126	6448	6601	6754	6938	7121	7216	7312	7440	7568	7866	8163	8270	8377
274	5848	6915	7279	7452	7625	7832	8039	8147	8254	8399	8544	8880	9215	9336	9456
290	6556	7753	8161	8355	8549	8781	9013	9133	9254	9416	9578	9955	10331	10466	10602
306	7305	8638	9093	9309	9525	9783	10042	10176	10311	10492	10672	11092	11511	11662	11812
322	8094	9571	10075	10314	10554	10840	11127	11276	11425	11625	11825	12290	12755	12922	13089

Forces in N

DRAG WITH WING ANGLE CHANGE





DRAG WITH WING ANGLE CHANGE

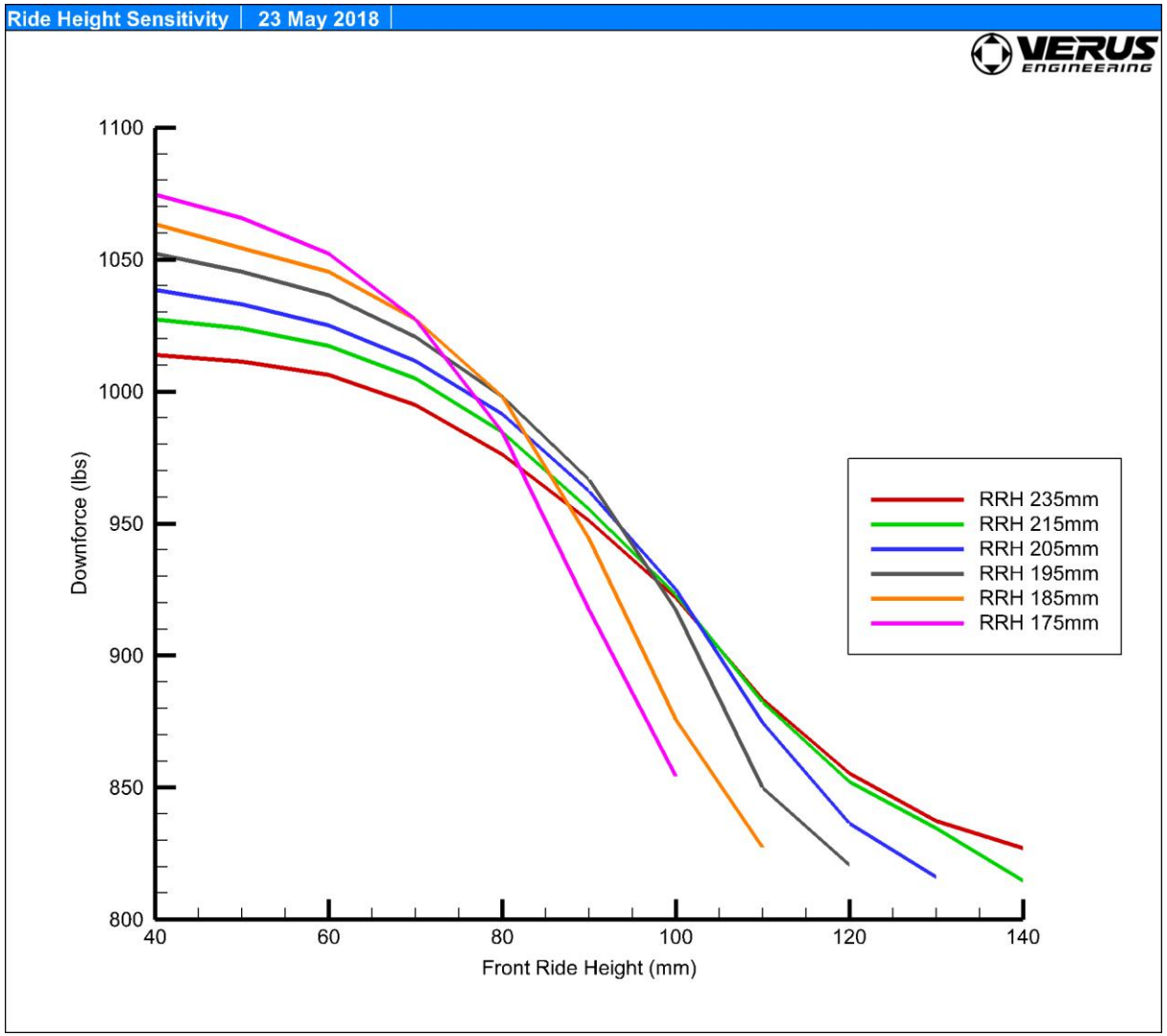
Velocity(mph)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
50	58	59	61	61	61	62	63	63	63	64	65	65	66	67	68
60	84	85	87	88	88	89	90	91	91	92	93	94	95	96	97
70	114	116	119	120	120	122	123	123	124	125	126	128	129	131	133
80	149	152	155	156	157	159	160	161	162	164	165	167	169	171	173
90	188	192	196	198	199	201	203	204	205	207	209	211	214	216	219
100	233	237	242	244	246	248	250	252	254	256	258	261	264	267	271
110	281	287	293	295	297	300	303	305	307	310	312	316	319	323	327
120	335	342	349	352	354	357	360	363	365	368	372	376	380	385	390
130	393	401	410	413	415	419	423	426	429	432	436	441	446	451	457
140	456	465	475	478	482	486	490	494	497	501	506	511	517	524	530
150	523	534	545	549	553	558	563	567	571	576	581	587	593	601	609
160	595	608	621	625	629	635	641	645	649	655	661	668	675	684	693
170	672	686	700	705	710	717	723	728	733	739	746	754	762	772	782
180	753	769	785	791	796	804	811	816	822	829	836	845	854	865	877
190	839	857	875	881	887	895	903	909	916	924	931	942	952	964	977
200	930	950	970	976	983	992	1001	1008	1014	1023	1032	1043	1055	1068	1082

Forces in lbs

Velocity(kph)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
80	259	264	270	271	273	276	278	280	282	284	287	290	293	297	301
97	372	380	388	391	394	397	401	403	406	410	413	418	422	428	433
113	507	518	528	532	536	541	545	549	553	558	562	569	575	582	590
129	662	676	690	695	700	706	712	717	722	728	735	743	751	760	770
145	838	856	873	880	886	894	902	908	914	922	930	940	950	962	975
161	1034	1056	1078	1086	1093	1103	1113	1121	1128	1138	1148	1160	1173	1188	1203
177	1251	1278	1305	1314	1323	1335	1347	1356	1365	1377	1389	1404	1419	1438	1456
193	1489	1521	1553	1564	1575	1589	1603	1614	1625	1639	1653	1671	1689	1711	1733
209	1748	1785	1822	1835	1848	1864	1881	1894	1907	1923	1940	1961	1982	2008	2034
225	2027	2070	2113	2128	2143	2162	2181	2196	2211	2230	2250	2274	2299	2329	2359
241	2327	2376	2426	2443	2460	2482	2504	2521	2538	2560	2583	2611	2639	2673	2708
257	2648	2704	2760	2780	2799	2824	2849	2869	2888	2913	2938	2970	3002	3042	3081
274	2989	3052	3116	3138	3160	3188	3216	3238	3260	3289	3317	3353	3389	3434	3478
290	3351	3422	3493	3518	3543	3574	3606	3631	3655	3687	3719	3759	3800	3849	3899
306	3734	3813	3892	3920	3947	3983	4018	4045	4073	4108	4144	4189	4234	4289	4344
322	4137	4225	4313	4343	4374	4413	4452	4482	4513	4552	4591	4641	4691	4752	4814

Forces in N

RIDE HEIGHT SENSITIVITY



Ride height sensitivity is used to show how ride height changes impact overall downforce of the vehicle. Since the vehicle moves dynamically around a track, it is imperative to know how downforce changes with these movements. The data to the left was calculated at a 10 degree angle of attack with the wing and at 120mph. With wing angle changes, the trends will be similar since the rear wing is not very sensitive to ride height changes.

SETUP STARTING POINT

This is for a generic starting point on where to setup your car for its first track outing. This is generic and will need to be adjusted based on the track and driver's style.

Ride Height
Front Ride Height : 90mm
Rear Ride Height : 205mm

Aerodynamic Adjustment
Rear Wing Angle : 6-7 degrees

Suspension
Set the starting point based on the specific manufactures recommendations
Our track car is running MCS 3-Way 600/800

Data acquisition is highly recommended to help properly setup the car. More than wing angle will need to be adjusted to get the setup where it is needed. The suspension will need to be tuned to optimize the car around the aerodynamic package.

UNDERSTEER ADJUSTMENTS

Understeer - also known as pushing or tight, is when the front wheels are traveling in a larger arc than the rear wheels. This feels like the front of the car is not turning in and “plowing” through the corner.

Aero Adjustment: Reduce rear wing angle of attack

Suspension Adjustment:

Corner Entry	Mid Corner	Corner Exit
1. Decrease front ride height (also changes aero loads) 2. Increase front camber 3. Increase toe-out 4. Decrease front damper compression 5. Decrease front ARB stiffness	1. Increase front spring pre-load 2. Increase front spring rate 3. Increase front ARB stiffness	1. Increase rear ride height (also changes aero loads) 2. Increase rear damper compression and rebound 3. Increase rear spring rate 4. Increase rear ARB stiffness

OVERSTEER ADJUSTMENTS

Oversteer - also known as loose, is when the front wheels are traveling in a smaller arc than the rear wheels. This feels like the back of the car is rotating around faster.

Aero Adjustment: Increase rear wing angle of attack

Suspension Adjustment:

Corner Entry	Mid Corner	Corner Exit
1. Increase rear camber 2. Increase rear toe-in 3. Increase front damper compression 4. Increase front ARB stiffness	1. Increase rear camber 2. Decrease rear spring rate 3. Decrease rear ARB stiffness 4. Decrease rear ride height (changes aero loads)	1. Decrease rear damper compression 2. Decrease rear ARB stiffness 3. Decrease rear ride height (changes aero loads)

ADJUSTING FOR ELEVATION, TEMPERATURE, & HUMIDITY

To correct data for atmospheric conditions like elevation, temperature, and humidity; density ratio should be used. To get a proper data, sign up for Davis Weather Station at www.weatherlink.com.

$$Density\ Ratio = \frac{\rho_{humid}}{\rho_0}$$

$$\rho_{humid} = \frac{P_{dry}}{T * R_{dry}} + \frac{P_{vapor}}{T * R_{vapor}}$$

$$R_{dry} = 287.05 \frac{J}{kg * K}$$

$$P_{dry} = 101{,}325\ Pa$$

$$T = Kelvin = ℃ + 273.15 = \frac{(℉ - 32) * 5}{9} + 273.15$$

$$\rho_0 = 1.225\ kg/m^3$$

$$R_{vapor} = 461.495 \frac{J}{kg * K}$$

$$P_{vapor} = Pa$$

$$1\ in\ of\ Hg = 3386.39\ Pa$$

To adjust the downforce levels for the weather condition, multiply the density ratio by the nominal downforce number on the graphs or charts.