PROJECT SEA TREE

Project Sea Tree is an analysis of high-performance sailplanes (capable of high-speed, low-drag flight) tethered to a moving root. That also requires high air loads on the wing. No one else is looking at harvesting power from high-performance sailplanes (L/D = 60, load factor > 5 and wing loading < 30Kg/m^2) towing a moving root with low retardation forces (low friction and drag) which allows the achievement of high surface velocities (>60 m/s). People are letting the kite circle around or move in a convoluted loop, but they are tethered to a system containing some point that does not move across the surface of the earth. As such, they do not qualify as a moving-root system, moving in a straight line. Low-performance traction kites can move in a straight line, but they are used for sport and for assisting transport ships, and they do not achieve high surface velocities. Project Sea Tree (no hardware yet) is summarized as follows:

Project Sea Tree will dramatically increase the production of power from the wind. The concept will harvest power from the wind using sailplanes tethered to a moving root. It advances a concept for a manned sail-craft propelled by the wind faster than any such existing vessel, and for harvesting more power from the wind than any existing device of the same size.

Why Is Project Sea Tree Astounding?

The power from this system using 71.4 square meters of wing area would exceed that from 14,812 square meters (over 3½ acres) of rotor area in an axial-flow wind turbine. (Betz Area Ratio = 207.)

A land-vehicle version of this system would be capable of ground speeds well in excess of 90 meters per second (201 mph) with a wind speed of only 6 meters per second (13.4 mph), far and away breaking land-sailing speed records.

The threshold wind velocity required to operate this system is a leisurely, uphill-walking pace of less than 1.2 meters per second (about 2.7 mph). It will be hard to find doldrums so calm as to fail that requirement.

The ocean version of this system takes advantage of the higher velocity and steadier wind at sea using acreage which is virtually unlimited in scope and costs nothing.

The generated power at sea is used to synthesize hydrocarbon in a process analogous to photosynthesis, that not only avoids the emission of carbon dioxide as a byproduct, but instead, it consumes carbon dioxide as a feedstock.

Kindle for PC: http://www.amazon.com/dp/B0053NYVMM

Printed version: https://www.createspace.com/3643072

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Model 04

There is concern that previous calculations for Project Sea Tree ignored tether drag and weight. The EVA was updated (model 04) to account for that. The material for the tether was assumed to be Spectra sold as Spectec-12. It has a specific gravity of 0.697 (density = 697 kg/m^3). Tether length and diameter are input parameters for model 04. That leads to tether weight, which model 04 adds to the weight of the air vehicle. Specific gravity was obtained by plotting vendor data on mass per unit length versus cross sectional area:

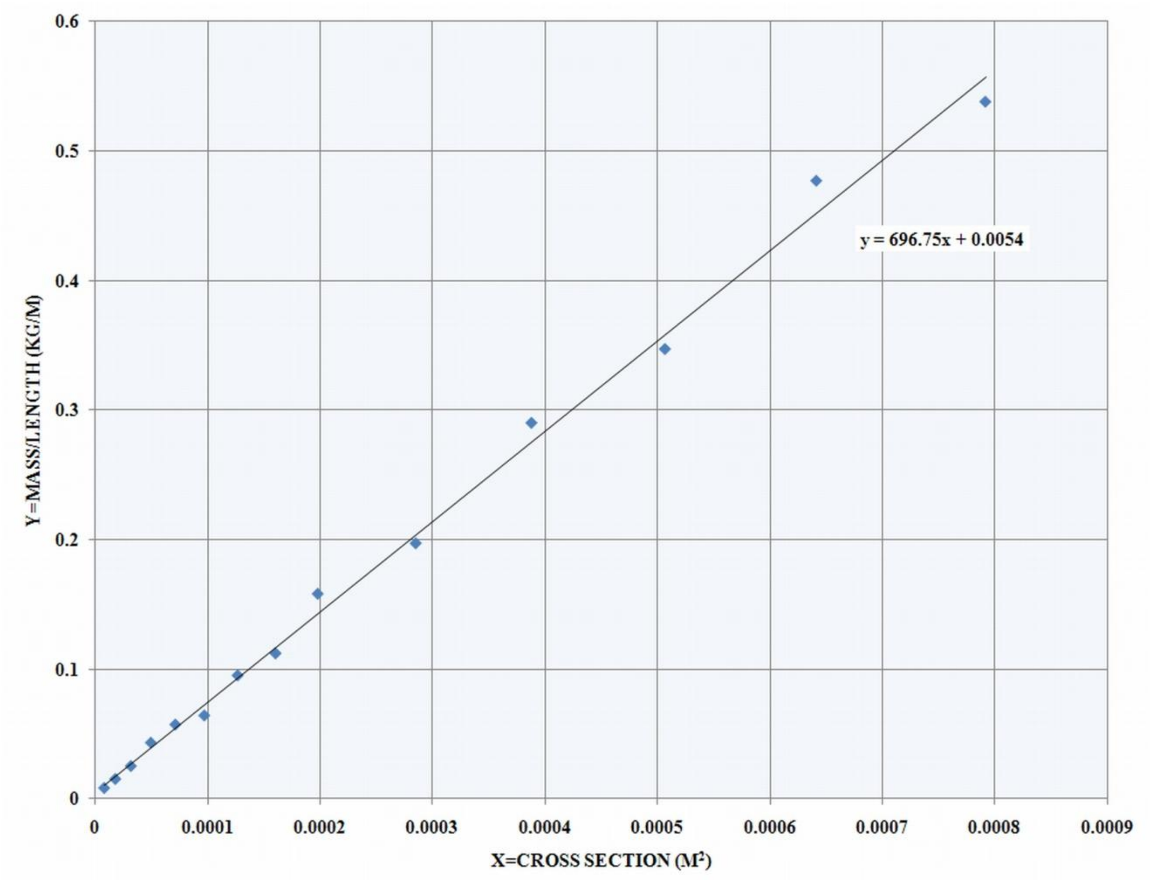


Figure 1. Mass/Length Versus Cross Sectional Area

The slope gives the density of 696.75 kg/m^3. Vendor data also yielded average tensile strength of 81.6x10^6 kg/m^2, or 115,900 PSI. The strength is used along with the load limit of the air vehicle to establish tether diameter. Tether length must be sufficient to provide ground clearance for the wing tip of the air vehicle when it has an angular altitude of about 5 or 6 degrees. Calculations below, for a variety of sailplanes, used a tether length of 500 m, and a diameter of 0.00476 m.

Tether drag is dependent on tether frontal area (length times diameter times sin(ϕ) where ϕ is the angular altitude), and on tether coefficient of drag, C_D. The effect of Reynolds Number on C_D is discussed at http://scienceworld.wolfram.com/physics/CylinderDrag.html where the following chart is shown:

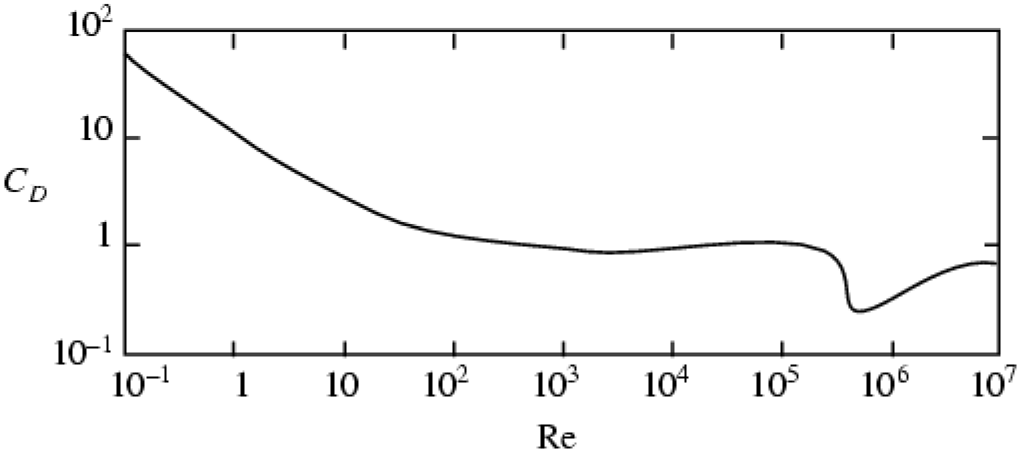


Figure 2 The Effect of Reynolds Number on Cylinder Drag

The references for that chart are:

Weisstein, Eric W. "Torque." *Eric Weisstein's World of Physics.* http://scienceworld.wolfram.com/physics/ CylinderDrag.html

J. D. Anderson, Fundamentals of Aerodynamics, 2nd ed. McGraw-Hill, 1991, pp. 228–236

An additional chart found by internet research appears to be in agreement with the above chart:

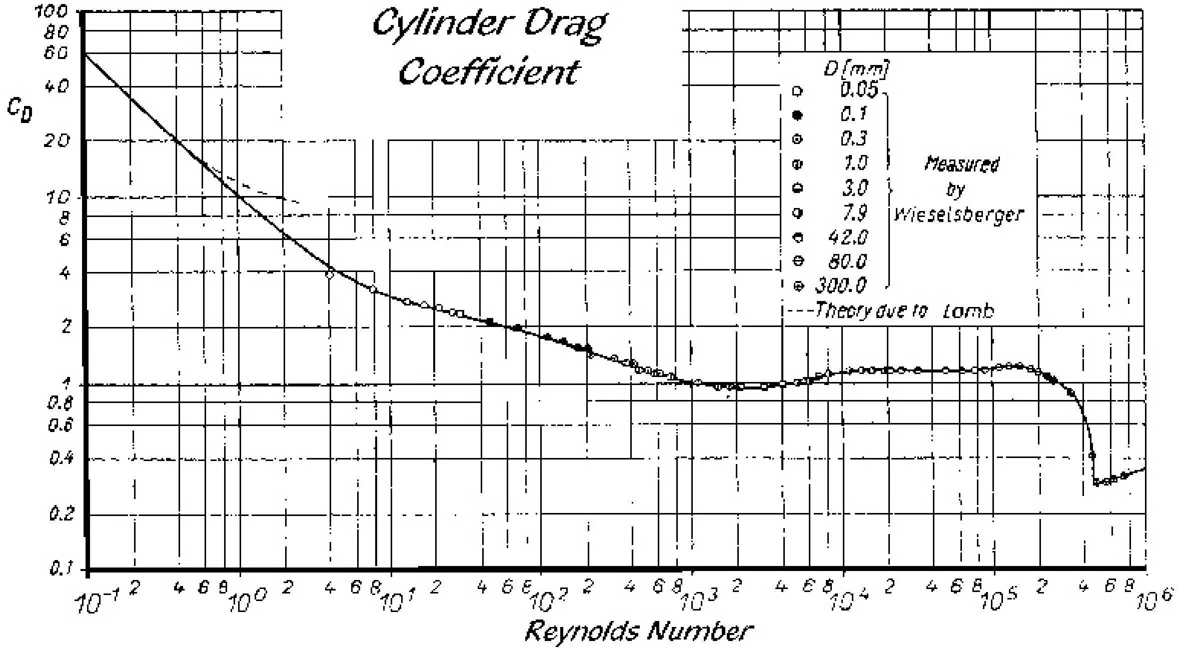


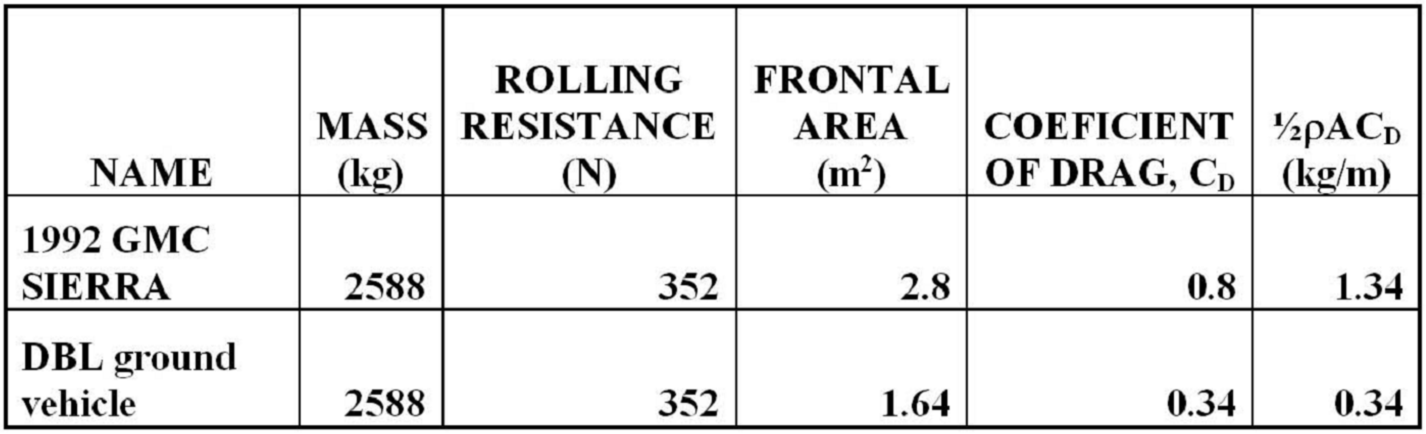
Figure 3 The Effect of Reynolds Number on Cylinder Drag (Second Source)

It is seen that C_D is close to unity for values of Re between 10^3 and 10^5.

The Reynolds Number for a cylinder with flow transverse to the axis is Re = vd/ν where the dynamic viscosity is $\nu = 15.1\text{x}10^{-6}$ m^2/s at STP (from Handbook of Chemistry and Physics). For these calculations, velocity is expected to be at least v = 45 m/s and tether diameter is expected to be at least d = 3/16" = 0.00476 m. This leads to $Re = 1.42\text{x}10^4$. So Re is in an area where $C_D = 1$ for a cylinder. This (along with velocity) leads to the calculation of tether drag which is added to drag of the air vehicle in model 04.

An attempt was made to evaluate the effects of tether weight and drag on the performance of several different manned sailplanes (assuming empty weight and radio control) and unmanned design-baseline air vehicles in the moving-root kite (MRK) system. The ground vehicle was assumed to be the design baseline (DBL) for the MRK (see Project Sea Tree). Parameters leading to calculation of retardation forces are shown in Table 1.

Table 1. DBL Ground Vehicle Friction and Drag Versus 1992 GMC Sierra



NAME	MASS (kg)	ROLLING RESISTANCE (N)	FRONTAL AREA (m^2)	COEFICIENT OF DRAG, C_D	$\frac{1}{2}\rho AC_D$ (kg/m)
1992 GMC SIERRA	2588	352	2.8	0.8	1.34
DBL ground vehicle	2588	352	1.64	0.34	0.34

Design and performance parameters for the sailplanes were obtained by internet research. Those parameters and results from the MRK spreadsheet for power and velocity are shown in Table 2. These sailplanes have a wide range of aspect ratios, wing spans and wing areas. Load factors range from around 5 for high lift/drag ratios to about 10 for aerobatic sailplanes. The configuration for the MRK system involved a total wing area of about 50 m^2. This area was achieved by stringing together anywhere from 3 to 8 air vehicles in a train.

TABLE 2. SAILPLANE PARAMETERS AND MRK PERFORMANCE

NAME	MODEL	MASS (KG)	WING SPAN (M)	WING AREA (M^2)	WING LOADING (KG/M^2)	ASPECT RATIO	MAX L/D	$C_{D,0}$	LOAD FACTOR	SPEED LIMIT (M/S)	LOAD LIMIT (N)	LOAD LIMIT/ WING AREA (N/M^2)	NUMBER IN TRAIN	TOTAL WING AREA (M^2)	S/W	MAX POWER (W)	POWER/ WING AREA (W/M^2)	BETZ AREA RATIO
SAILPLANES WITH COCKPIT (EMPTY)														Wind=6 m/s				
Glasflugel	Hornet	220.00	15.00	9.80	22.45	22.96	38.00	0.01192	5.3		11,438	1,167	5	49.0	14.33	306,780	6,261	81
MDM-1 FOX		345.00	14.00	12.30	28.05	15.93	28.00	0.01524	9.0	78	30,460	2,476	4	49.2	11.17	213,715	4,344	57
Sparrowhawk		70.45	11.00	6.50	10.83	18.62	37.00	0.01020	5.5	41	3,788	582	8	52.0	12.42	328,944	6,323	82
Swift	S-1	280.00	12.70	11.80	23.73	13.67	30.00	0.01139	10.0	80	27,468	2,328	4	47.2	11.17	199,234	4,221	55
Schleicher	ASW-20	255.00	15.00	10.49	24.31	21.45	43.00	0.00870	5.3	74	13,258	1,264	5	52.5	14.33	387,695	7,392	96
Schleicher	ASW-19	250.00	15.00	10.96	22.81	20.53	38.50	0.01039	5.3	68	12,998	1,186	5	54.8	14.33	299,279	5,461	91
Schleicher	1 – 23	162.70	13.41	13.83	11.76	13.00	25.10	0.01548	8.3	55	13,311	962	4	55.3	11.17	227,019	4,103	53
SZD	Puchacz	365.00	16.67	18.16	20.10	15.30	30.00	0.01275	5.3	60	18,977	1,045	3	54.5	12.42	278,265	5,108	66
SZD-51-1	JUNIOR	225.00	15.00	12.51	17.99	17.99	35.00	0.01101	5.3	61	11,698	935	4	50.0	12.42	282,237	5,640	73
SZD-38	Jantar-1	267.00	15.00	10.66	25.05	21.11	39.00	0.01041	5.3	79	13,882	1,302	5	53.3	14.33	369,347	6,930	90
Rolladen-Schneider	LS4a	238.00	15.00	10.20	23.33	22.06	41.00	0.00984	5.3	75	12,374	1,213	5	51.0	14.33	354,636	6,954	90
DG300	Elan	245.00	15.00	10.27	23.86	21.91	41.00	0.00977	5.3	75	12,738	1,240	5	51.4	14.33	359,311	6,997	91
SZD	Jantar-2	343.00	20.50	14.25	24.07	29.49	47.00	0.01001	5.3	69	17,834	1,251	4	57.0	15.00	530,061	9,299	121
Schempp-Hirth	Nimbus 3	485.00	24.60	16.85	28.78	35.91	57.00	0.00829	5.4	76	25,692	1,525	3	50.6	15.33	486,191	9,618	125
Schempp-Hirth	Nimbus 4	595.00	26.50	17.86	33.31	39.32	60.00	0.00819	5.3	79	30,936	1,732	3	53.6	17.33	580,496	10,834	141
Schneider	ES-65 Platypus	400.00	17.70	15.80	25.32	19.83	38.00	0.01030	5.3	72	20,797	1,316	3	47.4	12.42	277,543	5,855	76
BLANIK	LAK-17A	215.00	18.00	9.80	21.94	33.06	47.00	0.01122	5.3	76	11,178	1,141	5	49.0	14.33	380,599	7,767	101
SAILPLANES WITHOUT COCKPIT																		
Design Baseline	DBL	435.00	24.60	16.85	25.82	35.91	60.74	0.00730	6.0		25,578	1,518	3	50.6	15.67	510,179	10,093	131
Design Baseline	DBL03	545.00	26.50	17.86	30.52	39.32	62.71	0.00750	5.8		30,936	1,732	3	53.6	17.33	601,302	11,223	146

True wind velocity was 6 m/s. Net propulsive force on the ground vehicle was the propulsive component of tether tension minus retardation force (friction and drag) on the ground vehicle, and power was net propulsive force times ground speed. The ratio S/W was the ratio of ground speed at maximum power to true wind speed. That ratio ranged up to over 17, and even higher speeds were attainable before loss of power. The effect of tether weight and drag was to reduce S/W by about 30%. The Betz Area Ratio was the area swept out by an axial-flow wind turbine operating at the Betz limit required to generate the same power as the MRK divided by the total wing area of the MRK system. Taking tether weight and drag into account reduced power and the Betz area ratio by about 50%. However, these reduced values are apparently well in excess of those for any existing device for harvesting power from kites. Maximum power values range up to over 600 KW in a 6-m/s wind.

This wide variety of sailplanes effectively reveals the effect of the lift/drag ratio. The speed ratio, S/W, is plotted versus L/D in Figure 4.

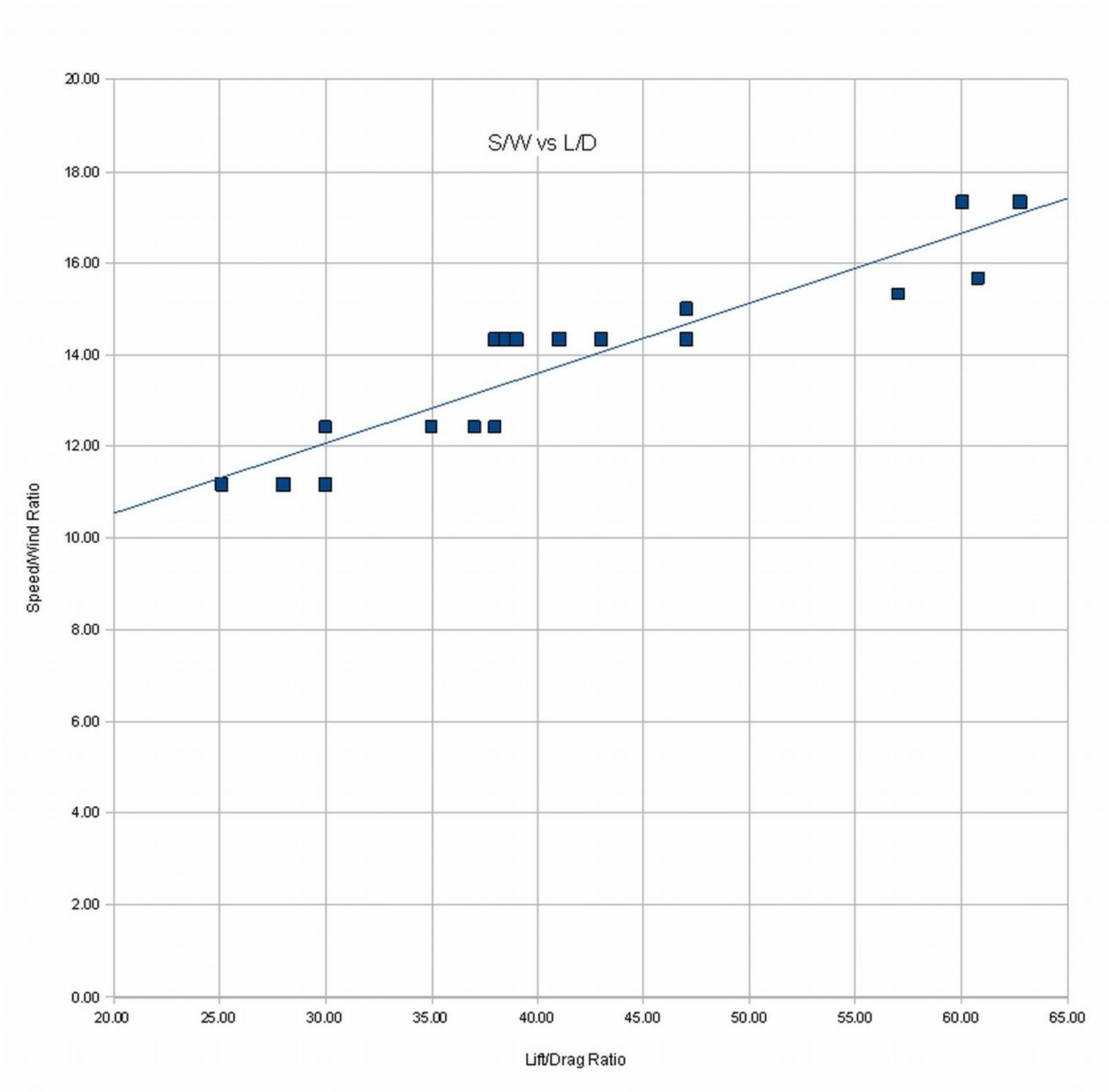


Figure 4. The Effect of Lift/Drag on S/W

These speeds are very high compared to those in other sail craft. Some say that ice boat speeds can range up to five times the speed of the wind. Wikipedia claims that speeds up to ten times the wind speed can be attained in modern ice-boat designs. Here, though, we see 17 times the speed of the wind. And that is under full-power conditions, so even higher speeds are attainable before loss of power in high-L/D MRK systems.

The effect of L/D on power is also important. The results for Betz Area Ratio in Table 2 are plotted versus L/D in Figure 5.

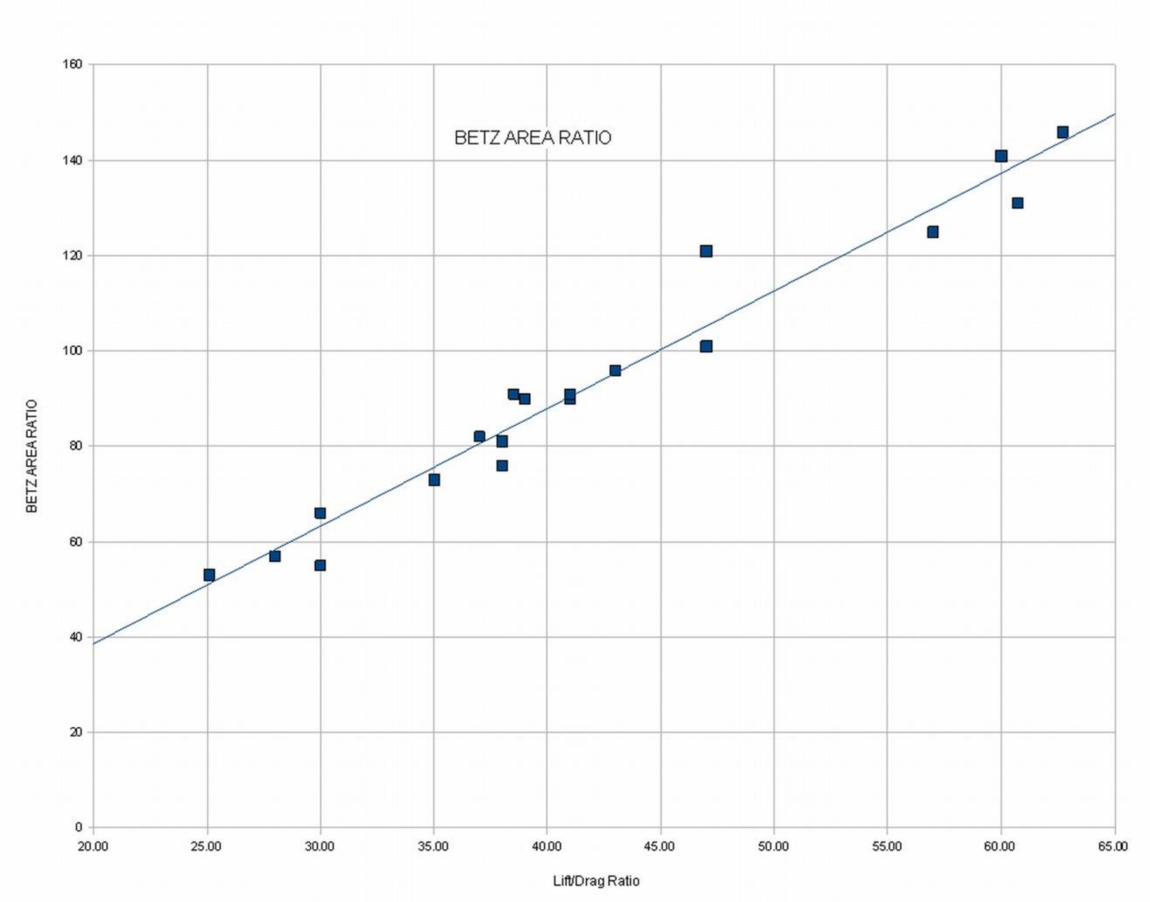


Figure 5. The Effect of Lift/Drag on Betz Area Ratio

This ratio (an indication of power production) increases strongly with L/D. The Betz Area Ratio ranges up to 146 for the design baseline DBL03 using a train of 3 air vehicles yielding a total wing area of 53.6 m^2. If a fourth air vehicle can be added with no additional drag, then the ratio would exceed 200. It is believed that this power-production area ratio is far in excess of that from any other kite system.