Project: Bullwinkle

By: *Gregory Hart*

Proof That A Flying Squirrel is Bull
or
Rocket Squirrel vs. Balboa the Flying Squirrel

The purpose of the experiment is to identify the point at which a flap of skin is adequate to accomplish genuine benefit for a regular squirrel during its evolution into a flying squirrel. The premise for the experiment is that there was a first mutation for a squirrel that consisted of excess skin at the armpits (or anywhere) and that this excess skin eventually evolved to form the completed wings of a flying squirrel. The experiment takes into consideration the "Laws of Evolution":

1) Changes occur randomly to each new generation
2) No two forms of life (> microscopic) are the exact same
3) Changes that increase the probability of survival are more probable to be passed on to future generations
4) Changes that decrease the probability of survival are less probable to be passed on to future generations
5) These changes create new and different forms of life

While following the Laws of Evolution, consideration must be given that mutations have a lesser probability of being passed down to future generations than do common or established traits. With this in mind, mutations are passed on when they create an advantage over not having the mutation. The advantage they create gives the animals with the mutation a higher probability to either survive or to produce more or stronger offspring. This advantage serves to eventually edge out the other animals without the mutation, with the eventual outcome to be that only the animals with the mutation have survived.

The experiment focuses on the first flap of skin mutation for a squirrel. Drawn into question is the concern that the first mutation might not be beneficial in a way that would serve the mutated squirrel to have an advantage over the squirrels without the mutation of the extra skin.

The expected conclusion is that the amount of skin necessary to introduce a benefit to the squirrel that would give it an advantage over the other squirrels is much larger than would be possible for a single mutation. Therefore, the focus of the experiment is on what the behaviors and gains would be for the squirrel which experiences the first mutation of extra skin, and not on complex learned behaviors.

The experiment performs a reverse engineering process of evolution using the rules of evolution that have been identified and accepted, thus identifying the steps that would occur during the process of a squirrel becoming modified to eventually have wings.

GIVENS:

1) Evolution does occur
2) There was a point in time when the ancestors of today's flying squirrels existed as squirrels without wings
3) The transition process for a squirrel to evolve wings involved an initial random mutation of an extra flap of skin of unknown size
4) The transition process for a squirrel to evolve wings involved the flap of skin (Given# 3) to grow in size over many generations of breading
5) Flight is complicated, and requires very specific control of the angle of flight ("Angle of Attack") to make best use of the airlift and drag

6) For any animal to accomplish flight or even a lengthy glide, the animal must use learned behavior to continuously modify the angle of its wings that control its Angle of Attack and establish its necessary airlift and drag

7) When referring to a “non-modified” squirrel, we will be referring to a typical and “average” squirrel that does not have any additional skin growth.

8) Non-modified squirrels that jump from tree to tree will execute a positive 9° initial Angle of Attack (upward) and can complete jumps to distances as great as 4 meters horizontally, without needing to perform an incline change during its motion and with minimal descent. They accomplish this because their body shape is similar to a bullet in both proportionate weight and aerodynamic design.

9) A non-modified squirrel is able to survive a drop of up to 30 meters by employing its tail as a parachute.

10) The model of the non-modified squirrel we will be using has dimensions:
   a. Body Length = 34.2 cm
   b. Arm Spans tip-to-tip = 34.2 cm
   c. Squirrel Weight = 0.43 kg

11) When referring to a “modified” squirrel, we will be referring to a typical and “average” Northern Flying Squirrel (Glaucomys sabrinus) that is outfitted with "wings" from additional skin growth beyond what non-modified squirrels have. When referring to a modified squirrel, reference will be made to the percentage of wing relative to the full wing span of today’s Northern Flying Squirrel.

12) A 100% modified squirrel will execute between a -5° initial Angle of Attack (downward) up to a positive 1° initial Angle of Attack (upward) and can complete jumps to distances as great as 90 meters horizontally. It accomplishes this by constantly performing changes to its flight inclination during its motion. They accomplish this because their body wing span creates a near perfect square, their bones are thinner, and their overall body is lighter. Flying squirrels show lengthening in bones of the lumbar vertebrae and forearm, whereas bones of the feet, hands, and distal vertebrae are reduced in length. Therefore, 100% modified squirrels are not well adapted for walking or running and must rely more heavily on their gliding abilities.

13) The model of the 100% modified squirrel we will be using has dimensions:
   a. Body Length = 34.2 cm
   b. Arm Spans tip-to-tip = 34.2 cm
   c. Wing Area = 13.69 cm^2 (larger than Body multiplied by Arms)
   d. Squirrel Weight = 0.14 kg

14) 100% modified squirrels accomplish long gliding distances by jumping off a branch at a negative degree Angle of Attack, and keeping their wings tightly tucked into their body. After free falling approximately 10 feet, they throw their wings out and catch air underneath them, thus providing lift. By maneuvering the angle of their head and body to point more or less upward or downward, they utilize this lift to propel forward. The formula that mathematically calculates forward propulsion is contingent on the force of propulsion generated from the air lift, and also the amount of drag that is created from the different angles.

15) The tail of the 100% modified squirrel contributes to maintaining a proper balance during flight. The tail has not been significantly modified in the evolutionary process from a non-modified squirrel to a 100% modified squirrel. Therefore, it is not considered in our mathematical calculations.

16) The evaluation of the 100% modified squirrel considers these squirrels to launch from a tree at heights of approximately 12 meters (40 feet). The non-modified squirrels typically jump at heights of approximately 4 meters (13 feet). The height increases relative to the percentage of

modification, because this is a learned behavior that could be easily learned by accident and that introduces a greater range to fall and thus make best use of gravity. This change of the launch height became necessary when evaluating the results, because when the height didn't increase, the addition of the wing was a negative for up to 52% modification in extremes, and up to 27% when given every conceivable consideration. Allowing the height to increase relative to the percentage of modification gave more advantage to disprove the original hypothesis, and was introduced to give the most amount of consideration to the disproof of the hypothesis.

17) Modifications to angles during the glide are not considered in this experiment because this learned behavior is not easily grasped, and therefore would not be an available resource to the first generations of mutations.

18) Environmental factors of wind, precipitation, falling objects, and predators are not considered in this experiment. All these factors would serve as a disadvantage to the modified squirrel's ability of horizontal gain. This is another advantage given to the disproof of the hypothesis.

19) How a flying squirrel achieves "flight"
    a. A flying squirrel does not actually fly, it glides
    b. The modern day Northern Flying Squirrel optimizes its glide by the following:
        i. The squirrel climbs high up a tree
        ii. The squirrel throws itself downward at an angle of approximately 5° descent. This approach is advantageous because it uses gravity to increase the speed of descent. Only because it has a wing does this become an advantage, as it uses the lift to propel itself upward or forward, depending on the angle of its wing. This is different from how a non-modified squirrel jumps, for which always jumps with an angle of ascent for the intent of optimizing forward propulsion for an object shaped as a bullet.
        iii. After freefalling approximately 25% of the total distance, it expands its wings to capture air
        iv. This capture resolves to lift the squirrel above its current height, sometimes resolving to become a height above where it originally jumped from
        v. The capture of lift, combined with controlled manipulation of the wing's angle, resolve to create greater heights and forward propulsion
    c. The benefits or losses from modifications to the "wing" can be mathematically calculated by creating engineering diagrams to represent the lift and resistance created by the introduction of wings. Other factors taken into consideration and set as constants instead of variables are the weight of the squirrel, the angle of ascent/descent at initial launch, and the distribution of wind resistance at differing wing angles while gliding. These constants were set to give the greatest advantage to accomplish vertical and horizontal gains.
    d. Such diagrams would represent the cost of drag (resistance) combining this cost with the gain from lift to represent the overall gain or loss from the introduction of a wing apparatus at a particular size. The size is reflected as a relative percentage, relative to the current size of a "wing" for an "average" Northern Flying Squirrel.
    e. Consideration must be given to the benefits of learned behavior to control the wings' angles and also to identify that an initial descent jump is required as opposed to an initial ascent jump. This difference in initial jump angle is needed to maximize gravity to capture lift that could only be appreciated from a winged apparatus, and would serve as detriment to a "bullet" formed device (non-modified squirrel).

THE EXPERIMENT:

(see statistics gathered in www.GHart.net/Project_Bullwinkle_Stats.pdf)

1) The experiment uses computer modeling to craft the aerodynamics of a flying squirrel and the mechanics of its glide. Using the same software approach that is used to design and build modern airplanes, the flight ability of a 100% modified squirrel was evaluated, and also the flight ability of a 10% modified squirrel, a 20% modified squirrel, a 21% modified squirrel, and a 30% modified squirrel.
2) The graphed numbers represent 4 columns that are consistent to all the graphs:
    a. Angle of Attack (a)
    b. Lift achieved (CL)
    c. Drag introduced (CD)
    d. Ratio of Lift to Drag (L/D)
3) It was calculated and confirmed that a non-modified squirrel can easily perform leaps and jumps that accomplish a horizontal gain of 3.32 meters (10 feet).
4) It was calculated and confirmed that a 100% modified squirrel can accomplish horizontal gains while gliding up to 89.3 meters (293 feet).
5) It was calculated and confirmed that a 10% modified squirrel can accomplish horizontal leaps and jumps that would amount to less than one meter (3 feet). This loss of distance is the result of drag produced by the 10% modification of additional wing. No actual glide is accomplished.
6) It was calculated and confirmed that a 20% modified squirrel can accomplish horizontal gains while gliding that would amount to 3.57 meters (11 feet).
7) It was calculated and confirmed that a 21% modified squirrel can accomplish horizontal gains while gliding that would amount to 4.56 meters (15 feet).
8) It was calculated and confirmed that a 30% modified squirrel can accomplish horizontal gains while gliding that would amount to 8.84 meters (29 feet).

ANALYSIS OF DATA:

The data returned demonstrates that the initial addition of skin to create the beginning formation of a wing will result in reducing the total horizontal distance gained. It is not until greater than 19% modification to the squirrel when the horizontal distance begins to increase. It increases aggressively after this point, resulting in a gain of almost 3 times the distance at 30% modification.

SUMMARY:

If we are willing to:

- decrease the weight of the squirrel from 0.43 kg to be only 0.35 kg
- alter the angle of attack from being a positive angle to instead be a negative angle
- introduce learned behavior of extreme complexity that accomplishes the task of balancing airlift by altering the angle of attack while in flight

With all these considerations provided without question or explanation, it will still require an addition of 19% formation/mutation of the skin of the wing that currently exists for a 100% modified flying squirrel before any appreciable gain would be realized. At 10% formation/mutation the squirrel is pitifully handicapped, both in walking and jumping.

If these factors are not taken into consideration, it will then require an addition of 51% formation/mutation of the skin of the wing that currently exists for a 100% modified flying squirrel before any appreciable gain would be realized.

SYNOPSIS:

Evolution occurs only to ensure that the least bad designs survive. The experiment has proven that the size of skin necessary and/or other bodily modifications or behavior modifications necessary to impart genuine benefit is too large to have reasonably occurred in a single mutation. When considering the amount of skin for 19% of the currently existing wing, such a large amount of skin would not occur as a first mutation.

If the first modification does not produce an advantage, then the squirrel with such modification would not have a greater probability to pass it on to future generations. The fact that the extra skin decreases performance of horizontal gains also confirms that the mutation would not get passed down because it decreases the probability for survival or fitness to reproduce. Further demonstration of this is that the introduction of any wing growth serves to decrease performance for running or climbing. Running and climbing are the most prime traits for survival of squirrels, the traits that provide an advantage over other animals of their eco-nitch.

It is accepted the fact that skin could have gradually grown over time. The dispute is in the original formation of such skin. The experiment has demonstrated that there must have been an additional driving factor creating the first modification of skin growth or most importantly, to allow the growth to persist and be passed on to future generations.

Because it cannot be possible for a random mutation to accomplish the necessary steps for a non-modified squirrel to become a modified squirrel, then it must be accepted that the mutation was not random. If the mutation which caused the evolution of the squirrel to a flying squirrel was not a random mutation, the only other possibility is that it was a controlled mutation.

If mutations that resolve to become evolutionary changes are controlled, then there must be a source for that control. The source of control for the evolutionary process must have a level of intelligence capable of looking forward into the future and identifying how to best satisfy needs. This intelligence must therefore have a degree of free will and a consciousness.

– END OF EXPERIMENT –

PROJECT: BULLWINKLE

ABSTRACT
Analyzing the flight characteristics of a Northern Flying Squirrel

By MK Designs For Database Engineers, Inc.

Contents

ORIGINAL SCOPE

PROJECT BULLWINKLE (proof that a flying squirrel is bull):
This experiment is focused more on the math than making a cool video. This is for scientific proof, and therefore does not have to be necessarily "pretty", as long as it is scientifically/mathematically accurate.

The highest purpose of the experiment is to identify the point at which a flap of skin is large enough to accomplish genuine benefit. Genuine enough to argue that it can increase the probability of survival enough to be a means of out-competing other squirrels and thus proven able to have occurred through natural selection.

My hypothesis is that such can NOT be proven, and we will reach a point where we conclude that the size of skin necessary to impart genuine benefit is too large to have reasonably occurred in a single mutation. I accept the fact that skin could have gradually grown over time. My dispute is in the original formation of it. My best guess is that this experiment will flush out the reality that there must have been an additional driving factor to create the first beginnings of a wing, more than a random mutation that was favorable.

My hypothesis is that benefit will not be accomplished until an amount of skin is added that is too large of a change to have occurred as a single mutation. This would prove that natural selection is NOT the only means of evolution, and that there must be a driving "intelligence" to the formula/program, that drives the direction of evolution.

Base Experiment:
Take a model of a regular squirrel, and apply a force of propulsion. This force can be derived by (as one possibility, please feel free to choose any reasonable method) taking the distance a current flying squirrel can launch and glide which is 30 meters, and

1. Building a digital computer model of such flying squirrel, and
2. Identify the amount of force needed to propel the Flying Squirrel 30 meters total distance (FYI: maximum recorded glide = 90 meters, average glide is 10 -15 meters) before it has fallen as described below.
3. Measure how far the digital squirrel model can reach before it starts its descent to the ground. Allow a 1 meter margin of falling before establishing the stop point (i.e. the squirrel starts at height X, propels forward, and when it has fallen to height X – 1 meter, identify that marker as the distance of glide achieved).
4. Start adding wings to the squirrel at 3 square cm increments. Eventually, additional modifications may be needed, such as elongation of the arms to accommodate a wider wing span while also allowing usage of its hands.
5. When the squirrel's total glide flight has become 1 or more meters longer in distance than it was without any wing addition (new flaps of skin), take one more measurement, and then end the experiment.

- Total Torso + Wingspan (new skin flaps) + Head + Tail of flying squirrel = approximately 800 square cm (45 cm head to tail X 30 cm wing span width).
- Initial wingspan = 0 square centimeters
- Initial span of Torso + Tail + Head + Appendages = approximately 350 square cm
- Wings will increase mostly between body and torso, but some also between hind legs and tail region, and also some between upper part of arm and neck (see picture from earlier)

INITIAL EXPERIMENTATION

During the early phases of calculations, the squirrel conditions were set at sea level and an Angle Of Attack (AoA) of 0 deg. Initially it was theorized that a squirrel would push of a branch and maintain a 0 deg AoA which would allow it to glide. The airfoil of its wings were assumed to be a flat plate. In reality, a squirrel’s wings are not rigid structures as an aircraft wing is. They are elongated parts of its skin which act as wings, since they are skin pieces they will have a factor of elasticity involved. In order to keep calculations simple, it was assumed that the squirrels’ wings are that of similar to an aircraft’s, rigid bodies.

However, after initial calculations it was clear that it would not be possible for the squirrel to glide at a 0 deg initial angle, a flat plate wing and no elasticity. The following reasons were ascertained:

1. The squirrels launch velocity of 17.21 ft/s is not enough for its wings to generate enough lift to compensate for its weight.
2. The flat plate airfoil will not generate lift at a o deg angle of attack.
3. The squirrels’ wings will act as air brakes instead of wings if a flat plate is used.
4. The launch velocity is too low and the wing area is too small.

To overcome the mentioned problems, the following solution was theorized.

To overcome the lack of an elasticity factor, the squirrels’ wings will be using a LIEBECK LA5055 airfoil. According to research from the Journal of Mammalogy, Vol 33, Issue 2, this airfoil closely mimics the flight characteristics of a flying squirrel.

The following scenarios will take different percentages of wing area of a flying squirrel to and ascertain the minimum wing area needed for flight at a 0-deg AoA.

SCENARIO 1:

The squirrel’s wing shall be set at 0-deg AoA and the squirrel will use a push off maneuver to launch from a branch which will allow it to glide. The following data was calculated.

From the above data the squirrel is able to fly at a distance of 99 meters with a launch height of 14 meters. At 0 deg AoA the squirrel will be generating a lift of 0.299 lbs, noting that weight of the squirrel is only 0.309 lbs the squirrel is able to achieve generate enough lift within a few moments of drop to compensate its weight. With a L/D ratio on the airfoil being 16.62 the squirrel is able to generate 16 times more lift than drag. The drag force being only 0.018. The sink rate of the squirrel being 0.1912 m/s the sink rate is the rate at which the squirrel is losing it altitude (vertical height). The sink rate is miniscule.

The calculations might seem a bit abnormal at first considering that a mammal such as the flying squirrel has such a high efficiency of lift.

During the calculations of drag the skin friction coefficient was taken into consideration. The skin friction coefficient accounts for the friction or drag that the surface of the wing generates when the aircraft is flying. Here, on the squirrel the skin friction coefficient is unknown. The skin friction coefficient can only be ascertained through wind-tunnel experimentation or flying squirrel observations. Therefore, the glide distance of squirrel might seem high however, they are correct given the skin friction coefficient.

SCENARIO 2:

The squirrels' wing shall be set at 0-deg AoA and the squirrel will use a push of maneuver to launch from a branch which will allow it to glide. The squirrel will only have 10% of its full wing area. The flowing data was calculated:

At 10% wing the squirrel is generating 0.0203 lbs of lift which when compared to the weight of the squirrel at 0.309 lbs is not enough for the squirrel to fly. However, the squirrel can generate more lift by diving down for a few meters to gain enough velocity for its wing to generate enough lift. But with only 10% of its regular wing area that also is not possible. Taking the sink rate into account the squirrel will need to drop more than 45 meters to generate the needed velocity. Therefore, a squirrel with a wing area 10% of a regular flying squirrel will not be able to fly.

An object falling for more than 12 seconds or 45 meters vertically down will reach terminal velocity. Terminal velocity is when a falling object will not gain any velocity, as in it will no longer accelerate. Meaning if a flying squirrel cannot generate the needed velocity by dropping 45 meters, it never will.

SCENARIO 3:

The squirrels' wing shall be set at 0-deg AoA and the squirrel will use a push of maneuver to launch from a branch which will allow it to glide. The squirrel will only have 20% of its full wing area. The flowing data was calculated:

At 20% wing the squirrel is generating 0.0102 lbs of lift which when compared to the weight of the squirrel at 0.309 lbs is not enough for the squirrel to fly. However, the squirrel can generate more lift by diving down for a few meters to gain enough velocity for its wing to generate enough lift. But with only 20% of its regular wing area that is not even possible. Taking the sink rate into account the squirrel will need to drop more than 35 meters to generate the needed velocity. Therefore, a squirrel with a wing area 20% of a regular flying squirrel will not be able to fly.

SCENARIO 4:

The squirrels' wing shall be set at 0-deg AoA and the squirrel will use a push of maneuver to launch from a branch which will allow it to glide. The squirrel will only have 52% of its full wing area. The following data was calculated:

At 52% wing the squirrel is generating 0.182 lbs of lift which when compared to the weight of the squirrel at 0.309 lbs is enough for the squirrel to fly. The squirrel can generate more lift by diving down for a few meters to gain enough velocity for its wing to generate enough lift. After dropping for 1 second the squirrel will have generated 9.81 m/s of vertical velocity after which a pitching angle of 3.5-deg will allow the squirrel to generate 0.325 lbs of lift, which will overcome its weight.

CONCLUSION

A flying squirrel will need at least 52% of its wing area to generate the necessary lift to overcome its weight, and gain horizontal distance relative to a launch without any wing addition. The squirrel will need to first drop at least 1 m then pitch at 3.5-deg to fly. This theory is proven correct when we look at the research done in the Journal Of Mammalogy, Vol 83, Issue, 2 1 May, 2002, Pages 553-562. The graph below shows the common flight paths taken by flying squirrels. According to the graph, a flying squirrel will first drop about 2-3 meters first to generate enough velocity for its wings to function then pitch up to generate enough lift for it to fly.

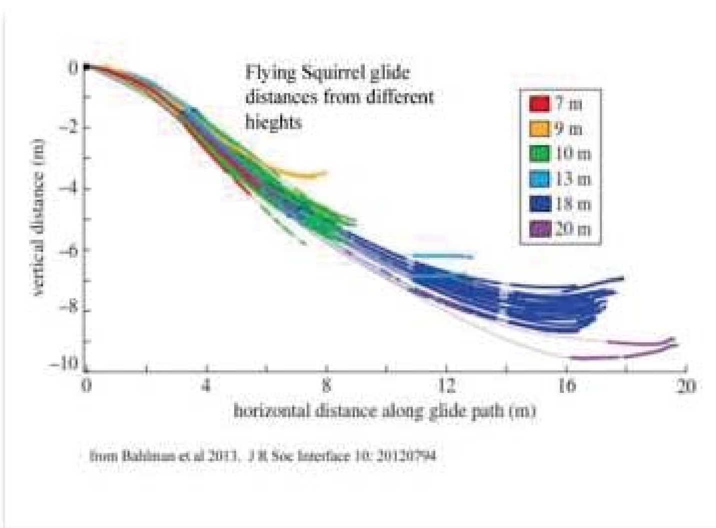


Figure 1. Squirrel Flight Paths

REFERENCES

1. Brian J. Stafford Richard W. Thorington, Jr. Takeo Kawamichi, Journal of Mammalogy, Volume 83, Issue 2, 1 May 2002, Pages 553–562, https://doi.org/10.1644/1545-1542(2002)083<0553:GBOJGF>2.0.CO;2

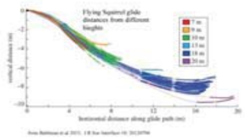
APPENDIX

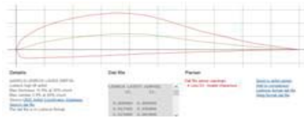
	Magnitude	Unit	
Geometric Dimensions	-	-	
Length	0.342	m	
Wing Chord Length	0.342	m	
S	0.1369	m^2	Area (flying squirrels have a square shaped wing)
S	1.473627557	ft2	More wing = more drag
Wing Span	0.37	m	
Squirrel Weight	0.14	kg	
S_{WET}	0.2738	m^2	Wetted area
Enviroment (Std.Sea Level)			
Density	1.224	kg/m^3	
Free Stream Velocity		m/s	
Dynamic Viscosity	1.79E-05	Pascal*s	
Temperature	288.15	K	
Pressure	101.325	kPa	
g	9.807	m/s^2	

Aerodynamics				
FLIGHT CONDITION				
Altitude (launch height in ft)	39.37008	ft		
Airspeed (KTAS)	10.2	Knots		
Airspeed	17.2176	ft/s		
Mach Number	0.015425904			
Density ratio	0.998848412			
Air density	0.002375262	slugs/ft³		
Outside Air Temperature	518.5595916	°R		
Viscosity (Sutherland's formula)	3.74404E-07	lbf·s/ft		
Reynolds Number (Re)	3991281.095			
Launch Height	12	m		
Launch Velocity (V0)	5.25	m/s		
Launch Acceleration	0.3	m/s^2		
Launch Force	0.042	kg*m / s^2		
Lift				
Max L/D				
MAX glide	0	m		
iw	0	deg	Incidence of the wing	
α_{0L}	-4.5	deg		
a_0	0.111	/deg		
e_w	1	-	span efficiency of the wing	
AR	1	-	Aspect ratio	CAUSE OF LOW CL
λw	0	-	Taper ratio	
a_w	0.036721303	/ deg	Clalpha of squirrel	
CL0	0.165245861		Zero lift coefficient	
Drag				
C_{dmisc}	0.006	-	Miscellaneous drag	
Location of maximum thickness ((x/c)max)	0.5			
Thickness ratio (t/c)	0.15			
Skin friction coeffcient	0.003540049		ASSUMPTION	$c_f = \frac{0.074}{Re^{0.2}}$
Interference Factor	1			
Form Factor	0.778243753			
Max thickness sweep angle	0			
Induced drag constant (K)	0.318309886		VERY HIGH	
$C_{dmin\ i}$	0.010062165		Minimum drag coefficient	
Range				
Range	89.29876986	m		

NOTES

The Liebeck aerofoil (C_L = 3.06 and C_D = 0.005), close example of the aerodynamics of Glaucomys sabrinus





From Equation (1.45),

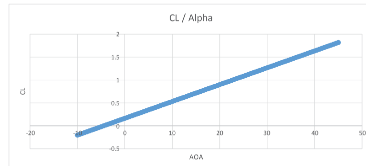
$$C_L = \frac{2W}{\rho_\infty V_\infty^2 S}$$

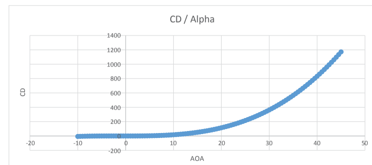
$$C_{L\alpha} = \frac{2\pi}{\left(1+\frac{2}{AR}\right)}$$

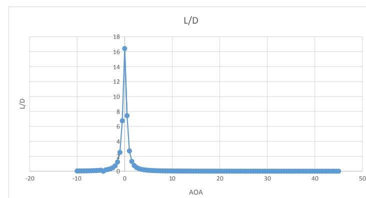
100% Modified

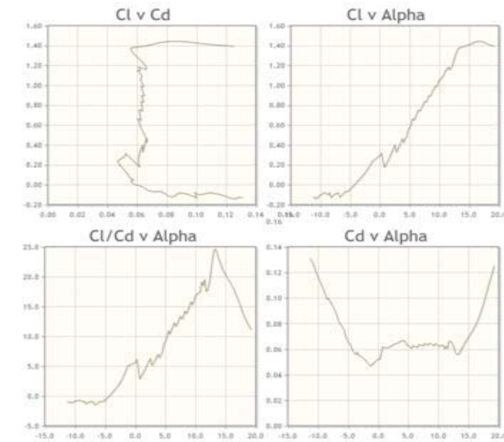
LIFT GENERATED BY WING

α	CL/Alpha	CD/Alpha	L/D	Sink Rate (m)	Lift (lb)	Drag (lb)
-10	-0.201967164	-6.418752327	0.031465175	#NUM!	-0.104784047	-3.330159375
-9.5	-0.183606513	-5.264487907	0.034876424	#NUM!	-0.095258224	-2.731307093
-9	-0.165245861	-4.25048853	0.03887691	#NUM!	-0.085732402	-2.205226734
-8.5	-0.14688521	-3.367987632	0.043612158	#NUM!	-0.076206579	-1.747370052
-8	-0.128524559	-2.608218646	0.049276758	#NUM!	-0.066680757	-1.353188803
-7.5	-0.110163908	-1.962415008	0.056136906	#NUM!	-0.057154935	-1.018134741
-7	-0.091803256	-1.421810153	0.064567872	#NUM!	-0.047629112	-0.737659621
-6.5	-0.073442605	-0.977637516	0.075122531	#NUM!	-0.03810329	-0.507215199
-6	-0.055081954	-0.62113053	0.088680158	#NUM!	-0.028577467	-0.322253228
-5.5	-0.036721303	-0.343522632	0.106896312	#NUM!	-0.019051645	-0.178225464
-5	-0.018360651	-0.136047255	0.134957896	#NUM!	-0.009525822	-0.070583661
-4.5	0	0.010062165	0	#DIV/0!	0	0.005220425
-4	0.018360651	0.103572194	0.177273943	53.81429293	0.009525822	0.05373504
-3.5	0.036721303	0.153249397	0.239617924	28.15193442	0.019051645	0.07950843
-3	0.055081954	0.167860339	0.328141561	16.78497408	0.028577467	0.087088838
-2.5	0.073442605	0.156171586	0.470268677	10.14300159	0.03810329	0.081024511
-2	0.091803256	0.126949702	0.723146687	5.899716441	0.047629112	0.065863694
-1.5	0.110163908	0.088961252	1.238335843	3.145056655	0.057154935	0.046154632
-1	0.128524559	0.050972803	2.521433996	1.430032534	0.066680757	0.026445569
-0.5	0.14688521	0.021750919	6.753057617	0.499455837	0.076206579	0.011284752
0	0.165245861	0.010062165	16.42249487	0.193634239	0.085732402	0.005220425
0.5	0.183606513	0.024673108	7.441564155	0.405394929	0.095258224	0.012800834
1	0.201967164	0.07435031	2.716426638	1.058883592	0.104784047	0.038574223
1.5	0.220327815	0.167860339	1.312566243	2.098121761	0.114309869	0.087088838
2	0.238688466	0.31396976	0.760227566	3.480384713	0.123835692	0.162892925
2.5	0.257049118	0.521445136	0.49295525	5.172149003	0.133361514	0.270534727
3	0.275409769	0.799053035	0.344670199	7.146496364	0.142887337	0.414562491
3.5	0.29377042	1.155560021	0.25422342	9.381385756	0.152413159	0.599524462
4	0.312131071	1.599732658	0.195114521	11.85846535	0.161938981	0.829968885
4.5	0.330491723	2.140337513	0.154411031	14.56223268	0.171464804	1.110444004
5	0.348852374	2.786141151	0.125209871	17.47942627	0.180990626	1.445498066
5.5	0.367213025	3.545910136	0.103559597	20.5985757	0.190516449	1.839679315
6	0.385573676	4.428411035	0.087068177	23.90966231	0.200042271	2.297535997
6.5	0.403934328	5.442410412	0.074219748	27.40385922	0.209568094	2.823616356
7	0.422294979	6.596674832	0.06401634	31.073329	0.219093916	3.422468638
7.5	0.44065563	7.899970861	0.055779399	34.91106415	0.228619738	4.098641089
8	0.459016281	9.361065064	0.049034621	38.91075978	0.238145561	4.856681953
8.5	0.477376933	10.98872401	0.043442435	43.0667108	0.247671383	5.701139475
9	0.495737584	12.79171425	0.038754586	47.37372813	0.257197206	6.636561901
9.5	0.514098235	14.77880237	0.034786191	51.82706972	0.266723028	7.667497475
10	0.532458886	16.95875492	0.031397286	56.42238335	0.276248851	8.798494444
10.5	0.550819538	19.34033847	0.028480346	61.15565872	0.285774673	10.03410105
11	0.569180189	21.93231959	0.025951664	66.02318711	0.295300495	11.37886554
11.5	0.58754084	24.74346483	0.023745294	71.02152717	0.304826318	12.83733617
12	0.605901491	27.78254077	0.021808714	76.14747567	0.31435214	14.41406116
12.5	0.624262143	31.05831398	0.020099679	81.39804247	0.323877963	16.11358878
13	0.642622794	34.57955101	0.018583896	86.7704288	0.333403785	17.94046726
13.5	0.660983445	38.35501843	0.017233298	92.26200851	0.342929608	19.89924485
14	0.679344096	42.3934828	0.01602473	97.87031166	0.35245543	21.9944698
14.5	0.697704748	46.7037107	0.014938957	103.5930102	0.361981252	24.23069035
15	0.716065399	51.29446869	0.013959895	109.4279052	0.371507075	26.61245474
15.5	0.73442605	56.17452332	0.013074006	115.3729159	0.381032897	29.14431123
16	0.752786701	61.35264118	0.012269834	121.4260699	0.39055872	31.83080805
16.5	0.771147353	66.83758882	0.01153763	127.5854938	0.400084542	34.67649345
17	0.789508004	72.6381328	0.010869057	133.8494062	0.409610365	37.68591568
17.5	0.807868655	78.7630397	0.010256951	140.2161099	0.419136187	40.86362298
18	0.826229307	85.22107608	0.009695129	146.6839861	0.42866201	44.2141636
18.5	0.844589958	92.0210085	0.00917823	153.2514884	0.438187832	47.74208578
19	0.862950609	99.17160353	0.00870159	159.917138	0.447713654	51.45193776
19.5	0.88131126	106.6816277	0.008261134	166.6795187	0.457239477	55.3482678
20	0.899671912	114.5598477	0.007853292	173.5372726	0.466765299	59.43562414
20.5	0.918032563	122.8150299	0.00747492	180.489097	0.476291122	63.71855502
21	0.936393214	131.455941	0.007123248	187.5337398	0.485816944	68.20160869
21.5	0.954753865	140.4913476	0.00679582	194.6699974	0.495342767	72.88933339
22	0.973114517	149.9300161	0.006490458	201.8967107	0.504868589	77.78627737
22.5	0.991475168	159.7807132	0.006205224	209.2127634	0.514394411	82.89698887
23	1.009835819	170.0522055	0.005938387	216.6170788	0.523920234	88.22601614
23.5	1.02819647	180.7532594	0.005688398	224.1086179	0.533446056	93.77790743
24	1.046557122	191.8926416	0.005453868	231.6863769	0.542971879	99.55721097
24.5	1.064917773	203.4791187	0.005233548	239.349386	0.552497701	105.568475
25	1.083278424	215.5214571	0.005026314	247.0967068	0.562023524	111.8162478
25.5	1.101639075	228.0284235	0.004831148	254.9274309	0.571549346	118.3050776
26	1.119999727	241.0087844	0.004647132	262.8406787	0.581075168	125.0395126
26.5	1.138360378	254.4713063	0.004473433	270.8355973	0.590600991	132.0241012
27	1.156721029	268.424756	0.004309293	278.9113598	0.600126813	139.2633914
27.5	1.17508168	282.8778998	0.004154024	287.0671636	0.609652636	146.7619316
28	1.193442332	297.8395045	0.004006998	295.3022296	0.619178458	154.5242701
28.5	1.211802983	313.3183365	0.003867641	303.6158005	0.628704281	162.554955
29	1.230163634	329.3231624	0.00373543	312.0071405	0.638230103	170.8585346
29.5	1.248524285	345.8627487	0.003609884	320.475534	0.647755926	179.4395572
30	1.266884937	362.9458622	0.003490562	329.0202846	0.657281748	188.302571
30.5	1.285245588	380.5812692	0.003377059	337.6407142	0.66680757	197.4521242
31	1.303606239	398.7777364	0.003269005	346.3361628	0.676333393	206.8927651
31.5	1.32196689	417.5440303	0.003166054	355.105987	0.685859215	216.629042
32	1.340327542	436.8889176	0.003067891	363.9495597	0.695385038	226.665503
32.5	1.358688193	456.8211647	0.002974223	372.8662692	0.70491086	237.0066965
33	1.377048844	477.3495382	0.002884781	381.855519	0.714436683	247.6571706
33.5	1.395409495	498.4828048	0.002799313	390.9167268	0.723962505	258.6214736
34	1.413770147	520.2297309	0.002717588	400.0493239	0.733488327	269.9041539
34.5	1.432130798	542.5990832	0.00263939	409.2527551	0.74301415	281.5097595
35	1.450491449	565.5996281	0.00256452	418.5264778	0.752539972	293.4428388
35.5	1.4688521	589.2401323	0.00249279	427.8699616	0.762065795	305.7079399
36	1.487212752	613.5293623	0.002424029	437.282688	0.771591617	318.3096113
36.5	1.505573403	638.4760847	0.002358073	446.7641498	0.78111744	331.252401
37	1.523934054	664.0890661	0.002294774	456.3138509	0.790643262	344.5408573
37.5	1.542294705	690.377073	0.002233989	465.9313057	0.800169084	358.1795285
38	1.560655357	717.348872	0.002175588	475.6160386	0.809694907	372.1729629
38.5	1.579016008	745.0132296	0.002119447	485.3675843	0.819220729	386.5257086
39	1.597376659	773.3789125	0.002065452	495.1854866	0.828746552	401.2423139
39.5	1.61573731	802.4546871	0.002013494	505.0692987	0.838272374	416.3273271
40	1.634097962	832.2493201	0.001963472	515.0185826	0.847798197	431.7852964
40.5	1.652458613	862.771578	0.001915291	525.0329092	0.857324019	447.62077
41	1.670819264	894.0302274	0.001868862	535.1118573	0.866849841	463.8382963
41.5	1.689179916	926.0340348	0.001824101	545.255014	0.876375664	480.4424233
42	1.707540567	958.7917668	0.00178093	555.4619743	0.885901486	497.4376995
42.5	1.725901218	992.31219	0.001739272	565.7323406	0.895427309	514.828673
43	1.744261869	1026.604071	0.00169906	576.0657227	0.904953131	532.6198921
43.5	1.762622521	1061.676176	0.001660226	586.4617374	0.914478954	550.815905
44	1.780983172	1097.537272	0.001622709	596.9200087	0.924004776	569.4212599
44.5	1.799343823	1134.196126	0.001586449	607.4401669	0.933530599	588.4405052
45	1.817704474	1171.661503	0.00155139	618.0218492	0.943056421	607.878189









	Magnitude	Unit	
Geometric Dimensions	-	-	
Length	0.342	m	
Wing Chord Length	0.342	m	
S	0	m2	Area (flying squirrels have a square shaped wing)
Wing Span	0	m	(MODIFY WING SPAN TO ALTER WING AREA)
Squirrel Weight	0.42	kg	
S_{WET}	0	m^2	Wetted area
% of wing evolved	0%		
Enviroment (Std.Sea Level)			
Density	1.225	kg/m^3	
Free Stream Velocity	-	m/s	
Dynamic Viscosity	1.79E-05	Pascal*s	
Temperature	288.15	K	
Pressure	101.325	kPa	
g	9.807	m/s^2	
Aerodynamics			
FLIGHT CONDITION			
Altitude (launch height in ft)	13.12336	ft	
Airspeed (KTAS)	10.2	Knots	
Airspeed	17.2176	ft/s	
Mach Number	0.015424512		
Density ratio	0.999616024		
Air density	0.002377087	slugs/ft^3	
Outside Air Temperature	518.6531972	°R	
Viscosity (Sutherland's formula)	3.74457E-07	lbf·s/ft	
Reynolds Number (Re)	3993775.961		
Launch Height	4	m	
Launch Velocity (V0)	5.25	m/s	
Launch Acceleration	0.3	m/s^2	
Launch Force	0.126	kg*m / s^2	
Lift			
Max L/D			
MAX glide	0	m	
iw	0	deg	Incidence of the wing
α_{0L}	-4.5	deg	
a_0	0.111	/deg	
e_w	1	-	span efficiency of the wing
AR	0	-	Aspect ratio CAUSE OF LOW CL
λw	0	-	Taper ratio
a_w	0	/ deg	Clalpha of squirrel
CL0	0		Zero lift coefficient
Drag			
C_{dmisc}	0.006	-	Miscellaneous drag
Location of maximum thickness ((x/c)max)	0.5		
Thickness ratio (t/c)	0.15		
Skin friction coeffcient	0.003539606		ASSUMPTIC $c_f = \frac{0.074}{Re^{0.2}}$
Interference Factor	1		
Form Factor	0.778231111		
Max thickness sweep angle	0		
Induced drag constant (K)	0		VERY HIGH
$C_{dmin\ i}$	0		Minimum drag coefficient
Range			
Range	3.32	m	No glide, just jump

NOTES

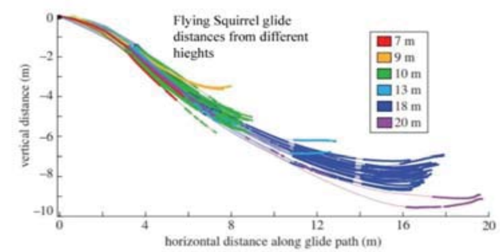
The Liebeck aerofoil (C_L = 3.06 and C_D = 0.005), close example of the aerodynamics of Glaucomys sabrinus

From Equation (1.45),

$$C_L = \frac{2W}{\rho_\infty V_\infty^2 S}$$

$$C_{L\alpha} = \frac{2\pi}{\left(1+\frac{2}{AR}\right)}$$

Non-Modified



from Bahlman et al 2013. J R Soc Interface 10: 20120794

α	CL/Alpha	CD/Alpha	L/D	
-4	0	0	0	
-3.5	0	0	0	
-3	0	0	0	
-2.5	0	0	0	
-2	0	0	0	
-1.5	0	0	0	
-1	0	0	0	
-0.5	0	0	0	
0	0	0	0	WING AREA IS 0 THEREFORE NO FLIGHT
0.5	0	0	0	
1	0	0	0	
1.5	0	0	0	
2	0	0	0	
2.5	0	0	0	
3	0	0	0	
3.5	0	0	0	
4	0	0	0	
4.5	0	0	0	
5	0	0	0	
5.5	0	0	0	
6	0	0	0	
6.5	0	0	0	
7	0	0	0	
7.5	0	0	0	
8	0	0	0	
8.5	0	0	0	
9	0	0	0	
9.5	0	0	0	
10	0	0	0	
10.5	0	0	0	
11	0	0	0	
11.5	0	0	0	
12	0	0	0	
12.5	0	0	0	
13	0	0	0	
13.5	0	0	0	
14	0	0	0	

	Magnitude	Unit	
Geometric Dimensions	-	-	
Length	0.342	m	
Wing Chord Length	0.342	m	
S	0.00116964	m2	Area (flying squirrels have a square shaped wing)
% of wing evolved	10%		
Wing Span	0.0342	m	(MODIFY WING SPAN TO ALTER WING AREA)
Squirrel Weight	0.39	kg	
S_{WET}	0.00233928	m^2	Wetted area
Enviroment (Std.Sea Level)			
Density	1.225	kg/m^3	
Free Stream Velocity		m/s	
Dynamic Viscosity	1.79E-05	Pascal*s	
Temperature	288.15	K	
Pressure	101.325	kPa	
g	9.807	m/s^2	

Aerodynamics			
FLIGHT CONDITION			
Altitude (launch height in ft)	16.40420	ft	
Airspeed (KTAS)	10.2	Knots	
Airspeed	17.2176	ft/s	
Mach Number	0.015424686		
Density ratio	0.999520048		
Air density	0.002376859	slugs/ft^3	
Outside Air Temperature	518.6414965	°R	
Viscosity (Sutherland's formula)	3.74451E-07	lbf·s/ft	
Reynolds Number (Re)	3993464.041		
Launch Height	5	m	
Launch Velocity (V0)	5.25	m/s	
Launch Acceleration	0.3	m/s^2	
Launch Force	0.117	kg*m / s^2	
Lift			
Max L/D			
MAX glide	0	m	
iw	0	deg	Incidence of the wing
α_{0L}	-4.5	deg	
a_0	0.111	/deg	
e_w	1	-	span efficiency of the wing
AR	1	-	Aspect ratio — CAUSE OF LOW CL
λw	0	-	Taper ratio
a_w	0.036721303	/ deg	Clalpha of squirrel
CL0	0.165245861		Zero lift coefficient
Drag			
C_{dmisc}	0.006	-	Miscellaneous drag
Location of maximum thickness ((x/c)max)	0.5		
Thickness ratio (t/c)	0.15		
Skin friction coeffcient	0.003539662		ASSUMPTION $c_f = \frac{0.074}{Re^{0.2}}$
Interference Factor	1		
Form Factor	0.778232691		
Max thickness sweep angle	0		
Induced drag constant (K)	0.318309886		VERY HIGH
$C_{dmin\ i}$	1.177576219		Minimum drag coefficient
Range			
Range	0.824966452	m	

NOTES

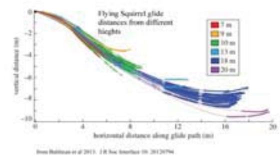
The Liebeck aerofoil (C_L = 3.06 and C_D = 0.005), close example of the aerodynamics of Glaucomys sabrinus

From Equation (1.45),

$$C_L = \frac{2W}{\rho_\infty V_\infty^2 S}$$

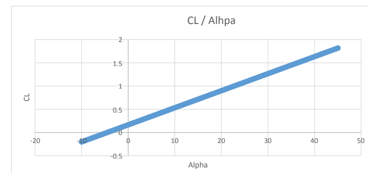
$$C_{L\alpha} = \frac{2\pi}{\left(1+\frac{2}{AR}\right)}$$

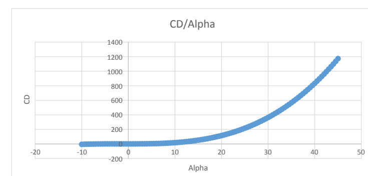
10% Modified

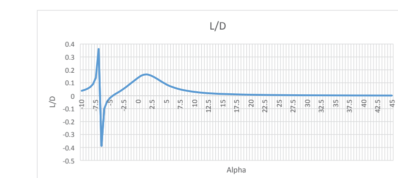


LIFT GENERATED BY WING

α	CL/Alpha	CD/Alpha	L/D	Sink Rate (m)	Lift (lb)	Drag (lb)
-10	-0.201967164	-5.251238274	0.038460865	#NUM!	-0.007115401	-0.185003659
-9.5	-0.183606513	-4.096973854	0.044815154	#NUM!	-0.006468546	-0.144338366
-9	-0.165245861	-3.082974477	0.053599491	#NUM!	-0.005821691	-0.108614679
-8.5	-0.14688521	-2.200473578	0.066751635	#NUM!	-0.005174837	-0.077523746
-8	-0.128524559	-1.440704593	0.089209516	#NUM!	-0.004527982	-0.050756718
-7.5	-0.110163908	-0.794900955	0.138588219	#NUM!	-0.003881128	-0.028004744
-7	-0.091803256	-0.2542961	0.361009297	#NUM!	-0.003234273	-0.008958974
-6.5	-0.073442605	0.189876537	-0.386791365	#NUM!	-0.002587418	0.006689442
-6	-0.055081954	0.546383523	-0.100811887	#NUM!	-0.001940564	0.019249355
-5.5	-0.036721303	0.823991421	-0.044565151	#NUM!	-0.001293709	0.029029615
-5	-0.018360651	1.031466798	-0.017800526	#NUM!	-0.000646855	0.036339073
-4.5	0	1.177576219	0	#DIV/0!	0	0.041486578
-4	0.018360651	1.271086248	0.014444851	3530.017008	0.000646855	0.044780982
-3.5	0.036721303	1.32076345	0.027803088	1296.826351	0.001293709	0.046531134
-3	0.055081954	1.335374392	0.041248323	713.7119029	0.001940564	0.047045884
-2.5	0.073442605	1.323685639	0.055483419	459.5117786	0.002587418	0.046634084
-2	0.091803256	1.294463755	0.070919913	321.5412281	0.003234273	0.045604583
-1.5	0.110163908	1.256475306	0.087676938	237.4263193	0.003881128	0.044266231
-1	0.128524559	1.218486856	0.105478822	182.7155741	0.004527982	0.04292788
-0.5	0.14688521	1.189264972	0.123509238	145.9638887	0.005174837	0.041898379
0	0.165245861	1.177576219	0.140327105	121.1231175	0.005821691	0.041486578
0.5	0.183606513	1.192187161	0.154008128	104.6998883	0.006468546	0.042001329
1	0.201967164	1.241864364	0.162632224	94.53375632	0.007115401	0.043751481
1.5	0.220327815	1.335374392	0.16499329	89.21398786	0.007762255	0.047045884
2	0.238688466	1.481483813	0.161114461	87.77759148	0.00840911	0.05219339
2.5	0.257049118	1.68895919	0.1521938	89.54243087	0.009055964	0.059502847
3	0.275409769	1.966567088	0.140045956	94.00991415	0.009702819	0.069283108
3.5	0.29377042	2.323074074	0.126457621	100.8056471	0.010349674	0.081843021
4	0.312131071	2.767246711	0.112794812	109.6418301	0.010996528	0.097491437
4.5	0.330491723	3.307851566	0.099911292	120.2926337	0.011643383	0.116537207
5	0.348852374	3.953655204	0.088235406	132.5776048	0.012290237	0.139289181
5.5	0.367213025	4.71342419	0.077907909	146.3501968	0.012937092	0.166056209
6	0.385573676	5.595925088	0.06890258	161.4896629	0.013583947	0.197147141
6.5	0.403934328	6.609924465	0.061110279	177.8952096	0.014230801	0.232870829
7	0.422294979	7.764188885	0.054390096	195.4817041	0.014877656	0.273536121
7.5	0.44065563	9.067484914	0.048597338	214.1764704	0.015524511	0.319451869
8	0.459016281	10.52857912	0.043597173	233.9168624	0.016171365	0.370926923
8.5	0.477376933	12.15623806	0.03927012	254.6484004	0.01681822	0.428270133
9	0.495737584	13.95922831	0.035513251	276.3233224	0.017465074	0.49179035
9.5	0.514098235	15.94631642	0.03223931	298.8994449	0.018111929	0.561796423
10	0.532458886	18.12626897	0.029374985	322.3392575	0.018758784	0.638597203
10.5	0.550819538	20.50785252	0.026858957	346.6091965	0.019405638	0.722501541
11	0.569180189	23.09983364	0.024640012	371.679056	0.020052493	0.813818287
11.5	0.58754084	25.91097888	0.022675363	397.5215077	0.020699347	0.91285629
12	0.605901491	28.95005483	0.0209292	424.1117051	0.021346202	1.019924403
12.5	0.624262143	32.22582803	0.019371485	451.4269551	0.021993057	1.135331473
13	0.642622794	35.74706506	0.017976939	479.4464444	0.022639911	1.259386353
13.5	0.660983445	39.52253248	0.016724218	508.1510085	0.023286766	1.392397892
14	0.679344096	43.56099686	0.015595238	537.5229376	0.02393362	1.534674941
14.5	0.697704748	47.87122475	0.014574617	567.5458101	0.024580475	1.68652635
15	0.716065399	52.46198274	0.013649225	598.2043512	0.02522733	1.84826097
15.5	0.73442605	57.34203738	0.012807812	629.4843111	0.025874184	2.020187649
16	0.752786701	62.52015523	0.012040704	661.3723594	0.026521039	2.20261524
16.5	0.771147353	68.00510287	0.011339551	693.8559939	0.027167893	2.395852593
17	0.789508004	73.80564685	0.010697122	726.9234607	0.027814748	2.600208557
17.5	0.807868655	79.93055375	0.010107132	760.5636848	0.028461603	2.815991982
18	0.826229307	86.38859013	0.009564102	794.7662084	0.029108457	3.043511721
18.5	0.844589958	93.18852255	0.00906324	829.521137	0.029755312	3.283076621
19	0.862950609	100.3391176	0.008600341	864.8190916	0.030402166	3.534995535
19.5	0.88131126	107.8491418	0.008171704	900.6511657	0.031049021	3.799577312
20	0.899671912	115.7273617	0.007774064	937.008888	0.031695876	4.077130802
20.5	0.918032563	123.982544	0.007404531	973.8841882	0.03234273	4.367964857
21	0.936393214	132.6234551	0.00706054	1011.269366	0.032989585	4.672388325
21.5	0.954753865	141.6588616	0.00673981	1049.157066	0.033636439	4.990710059
22	0.973114517	151.0975302	0.006440307	1087.54025	0.034283294	5.323238907
22.5	0.991475168	160.9482273	0.006160212	1126.412175	0.034930149	5.67028372
23	1.009835819	171.2197195	0.005897894	1165.766377	0.035577003	6.032153349
23.5	1.02819647	181.9207735	0.005651891	1205.596647	0.036223858	6.409156643
24	1.046557122	193.0601557	0.005420886	1245.897019	0.036870712	6.801602454
24.5	1.064917773	204.6466327	0.005203691	1286.661751	0.037517567	7.209799631
25	1.083278424	216.6889711	0.004999232	1327.885315	0.038164422	7.634057025
25.5	1.101639075	229.1959375	0.004806538	1369.56238	0.038811276	8.074683486
26	1.119999727	242.1762984	0.004624729	1411.687803	0.039458131	8.531987865
26.5	1.138360378	255.6388204	0.004453003	1454.256617	0.040104985	9.006279011
27	1.156721029	269.59227	0.004290631	1497.264024	0.04075184	9.497865776
27.5	1.17508168	284.0454139	0.00413695	1540.705379	0.041398695	10.00705701
28	1.193442332	299.0070185	0.003991352	1584.576189	0.042045549	10.53416156
28.5	1.211802983	314.4858505	0.003853283	1628.872101	0.042692404	11.07948828
29	1.230163634	330.4906764	0.003722234	1673.588897	0.043339258	11.64334602
29.5	1.248524285	347.0302628	0.003597739	1718.722483	0.043986113	12.22604363
30	1.266884937	364.1133762	0.003479369	1764.268888	0.044632968	12.82788996
30.5	1.285245588	381.7487832	0.003366731	1810.224254	0.045279822	13.44919386
31	1.303606239	399.9452504	0.003259462	1856.584834	0.045926677	14.09026418
31.5	1.32196689	418.7115444	0.003157226	1903.346985	0.046573532	14.75140977
32	1.340327542	438.0564316	0.003059714	1950.50716	0.047220386	15.43293949
32.5	1.358688193	457.9886787	0.002966641	1998.061911	0.047867241	16.13516217
33	1.377048844	478.5170523	0.002877742	2046.007878	0.048514095	16.85838668
33.5	1.395409495	499.6503188	0.002792772	2094.341789	0.04916095	17.60292186
34	1.413770147	521.397245	0.002711503	2143.060454	0.049807805	18.36907656
34.5	1.432130798	543.7665972	0.002633723	2192.160762	0.050454659	19.15715964
35	1.450491449	566.7671421	0.002559237	2241.639679	0.051101514	19.96747993
35.5	1.4688521	590.4076463	0.002487861	2291.494245	0.051748368	20.80034631
36	1.487212752	614.6968764	0.002419425	2341.721568	0.052395223	21.6560676
36.5	1.505573403	639.6435988	0.002353769	2392.318824	0.053042078	22.53495267
37	1.523934054	665.2565802	0.002290746	2443.283254	0.053688932	23.43731037
37.5	1.542294705	691.5445871	0.002230217	2494.612161	0.054335787	24.36344953
38	1.560655357	718.5163861	0.002172053	2546.302909	0.054982641	25.31367903
38.5	1.579016008	746.1807437	0.002116131	2598.352919	0.055629496	26.2883077
39	1.597376659	774.5464265	0.002062338	2650.759666	0.056276351	27.2876444
39.5	1.61573731	803.6222012	0.002010568	2703.52068	0.056923205	28.31199797
40	1.634097962	833.4168342	0.001960721	2756.633544	0.05757006	29.36167727
40.5	1.652458613	863.9390921	0.001912703	2810.095888	0.058216914	30.43699114
41	1.670819264	895.1977414	0.001866425	2863.905393	0.058863769	31.53824844
41.5	1.689179916	927.2015489	0.001821804	2918.059785	0.059510624	32.66575802
42	1.707540567	959.9592809	0.001778764	2972.556834	0.060157478	33.81982873
42.5	1.725901218	993.4797041	0.001737228	3027.394356	0.060804333	35.00076942
43	1.744261869	1027.771585	0.00169713	3082.570206	0.061451187	36.20888893
43.5	1.762622521	1062.84369	0.001658402	3138.082284	0.062098042	37.44449613
44	1.780983172	1098.704786	0.001620984	3193.928525	0.062744897	38.70789985
44.5	1.799343823	1135.36364	0.001584817	3250.106904	0.063391751	39.99940895
45	1.817704474	1172.829017	0.001549846	3306.615435	0.064038606	41.31933228







	Magnitude	Unit		
Geometric Dimensions	-	-		
Length	0.342	m		
Wing Chord Length	0.342	m		
S	0.00467856	m^2	Area (flying squirrels have a square shaped wing)	
% of wing evolved	20%			
Wing Span	0.0684	m	(MODIFY WING SPAN TO ALTER WING AREA)	
Squirrel Weight	0.36	kg		
S_{WET}	0.00935712	m²	Wetted area	
Enviroment (Std.Sea Level)				
Density	1.225	kg/m^3		
Free Stream Velocity		m/s		
Dynamic Viscosity	1.79E-05	Pascal*s		
Temperature	288.15	K		
Pressure	101.325	kPa		
g	9.807	m/s^2		
Aerodynamics				
FLIGHT CONDITION				
Altitude (launch height in ft)	19.68504	ft		
Airspeed (KTAS)	10.2	Knots		
Airspeed	17.2176	ft/s		
Mach Number	0.01542486			
Density ratio	0.999424079			
Air density	0.00237663	slugs/ft³		
Outside Air Temperature	518.6297958	*R		
Viscosity (Sutherland's formula)	3.74444E-07	lbf-s/ft		
Reynolds Number (Re)	3993152.138			
Launch Height	6	m		
Launch Velocity (V0)	5.25	m/s		
Launch Acceleration	0.3	m/s^2		
Launch Force	0.108	kg*m / s^2		
Lift				
Max L/D				
MAX glide	0	m		
iw	0	deg	Incidence of the wing	
α_{0L}	-4.5	deg		
a_0	0.111	/deg		
e_w	1	-	span efficiency of the wing	
AR	1	-	Aspect ratio	CAUSE OF LOW CL
λw	0	-	Taper ratio	
a_w	0.036721303	/ deg	Clalpha of squirrel	
CL0	0.165245861		Zero lift coefficient	
Drag				
C_{Dmisc}	0.006	-	Miscellaneous drag	
Location of maximum thickness ((x/c)max)	0.5			
Thickness ratio (t/c)	0.15			
Skin friction coeffcient	0.003539717		ASSUMPTION	$c_f = \frac{0.074}{Re^{0.2}}$
Interference Factor	1			
Form Factor	0.778234271			
Max thickness sweep angle	0			
Induced drag constant (K)	0.318309886		VERY HIGH	
$C_{Dmin\,i}$	0.294399251		Minimum drag coefficient	
Range				
Range	3.565057397	m		

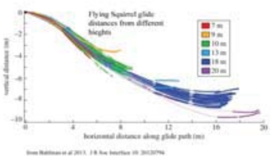
NOTES

The Liebeck aerofoil (C_L = 3.06 and C_D = 0.005), close example of the aerodynamics of Glaucomys sabrinus

From Equation (1.45),

$$C_L = \frac{2W}{\rho_\infty V_\infty^2 S}$$

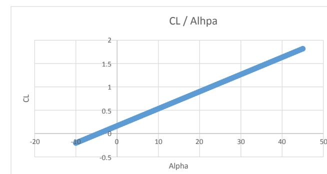
$$C_{L\alpha} = \frac{2\pi}{\left(1+\frac{2}{AR}\right)}$$

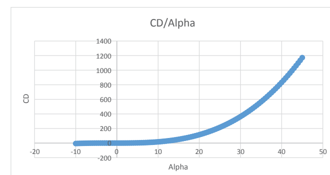


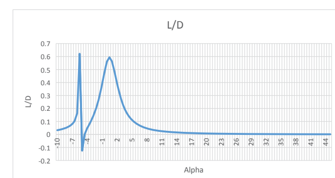
20% Modified

LIFT GENERATED BY WING

α	CL/Alpha	CD/Alpha	L/D	Sink Rate (m)	Lift	Drag (lb)
-10	-0.201967164	-6.134415241	0.032923621	#NUM!	#REF!	-0.432195317
-9.5	-0.183606513	-4.980150821	0.036867661	#NUM!	#REF!	-0.350872541
-9	-0.165245861	-3.966151444	0.041664032	#NUM!	#REF!	-0.279432026
-8.5	-0.14688521	-3.083650546	0.047633546	#NUM!	#REF!	-0.217256132
-8	-0.128524559	-2.32388156	0.055305985	#NUM!	#REF!	-0.163727216
-7.5	-0.110163908	-1.678077923	0.065648863	#NUM!	#REF!	-0.118227637
-7	-0.091803256	-1.137473068	0.08070807	#NUM!	#REF!	-0.080139755
-6.5	-0.073442605	-0.69330043	0.105931861	#NUM!	#REF!	-0.048845927
-6	-0.055081954	-0.336793444	0.163548177	#NUM!	#REF!	-0.023728513
-5.5	-0.036721303	-0.059185546	0.620443759	#NUM!	#REF!	-0.00416987
-5	-0.018360651	0.148289831	-0.123815983	#NUM!	#REF!	0.010447641
-4.5	0	0.294399251	0	#DIV/0!	#REF!	0.020741664
-4	0.018360651	0.38790928	0.047332333	761.7578701	#REF!	0.027329838
-3.5	0.036721303	0.437586483	0.083917817	303.8125326	#REF!	0.030829806
-3	0.055081954	0.452197425	0.121809525	170.8964271	#REF!	0.031859208
-2.5	0.073442605	0.440508672	0.166722269	108.1312579	#REF!	0.031035686
-2	0.091803256	0.411286787	0.223209836	72.23979947	#REF!	0.028976882
-1.5	0.110163908	0.373298338	0.295109558	49.87879594	#REF!	0.026300436
-1	0.128524559	0.335309889	0.38330083	35.55380466	#REF!	0.02362399
-0.5	0.14688521	0.306088005	0.479879014	26.56428373	#REF!	0.021565185
0	0.165245861	0.294399251	0.561298511	21.41212239	#REF!	0.020741664
0.5	0.183606513	0.309010193	0.594176233	19.18932003	#REF!	0.021771066
1	0.201967164	0.358687396	0.563072932	19.30695875	#REF!	0.025271033
1.5	0.220327815	0.452197425	0.487238102	21.36205339	#REF!	0.031859208
2	0.238688466	0.598306845	0.398939889	25.06661689	#REF!	0.04215323
2.5	0.257049118	0.805782222	0.319005695	30.20733473	#REF!	0.056770742
3	0.275409769	1.083390121	0.254211076	36.62138479	#REF!	0.076329384
3.5	0.29377042	1.439897106	0.204021814	44.18127707	#REF!	0.101446798
4	0.312131071	1.884069744	0.165668533	52.78498147	#REF!	0.132740626
4.5	0.330491723	2.424674599	0.136303536	62.34928612	#REF!	0.170828509
5	0.348852374	3.070478237	0.113614996	72.8052005	#REF!	0.216328087
5.5	0.367213025	3.830247222	0.095871886	84.09469368	#REF!	0.269857003
6	0.385573676	4.712748121	0.08181504	96.16832835	#REF!	0.332032898
6.5	0.403934328	5.726747497	0.070534684	108.9835107	#REF!	0.403473413
7	0.422294979	6.881011918	0.061371058	122.5031726	#REF!	0.484796189
7.5	0.44065563	8.184307947	0.053841526	136.694764	#REF!	0.576618868
8	0.459016281	9.64540215	0.047589128	151.5294709	#REF!	0.679559091
8.5	0.477376933	11.27306109	0.0423467	166.9816003	#REF!	0.794234499
9	0.495737584	13.07605134	0.037911872	183.0280914	#REF!	0.921262734
9.5	0.514098235	15.06313945	0.034129554	199.6481223	#REF!	1.061261437
10	0.532458886	17.243092	0.030879548	216.8227902	#REF!	1.21484825
10.5	0.550819538	19.62467556	0.028067702	234.5348495	#REF!	1.382640814
11	0.569180189	22.21665667	0.025619525	252.7684952	#REF!	1.565256769
11.5	0.58754084	25.02780192	0.023475527	271.5091823	#REF!	1.763313758
12	0.605901491	28.06687786	0.021587777	290.7434738	#REF!	1.977429422
12.5	0.624262143	31.34265106	0.019917337	310.4589128	#REF!	2.208221402
13	0.642622794	34.86388809	0.018432333	330.6439134	#REF!	2.456307339
13.5	0.660983445	38.63935551	0.017106482	351.2876671	#REF!	2.722304875
14	0.679344096	42.67781989	0.015917966	372.3800623	#REF!	3.006831651
14.5	0.697704748	46.98804779	0.014848558	393.9116152	#REF!	3.310505309
15	0.716065399	51.57880577	0.013882939	415.8734087	#REF!	3.63394349
15.5	0.73442605	56.45886041	0.013008163	438.2570399	#REF!	3.977763834
16	0.752786701	61.63697826	0.012213232	461.0545736	#REF!	4.342583985
16.5	0.771147353	67.1219259	0.011488755	484.2585013	#REF!	4.729021582
17	0.789508004	72.92246989	0.010826677	507.8617053	#REF!	5.137694267
17.5	0.807868655	79.04737679	0.010220056	531.8574264	#REF!	5.569219682
18	0.826229307	85.50541316	0.009662889	556.2392353	#REF!	6.024215467
18.5	0.844589958	92.30534558	0.009149957	581.0010071	#REF!	6.503299265
19	0.862950609	99.45594061	0.008676713	606.1368984	#REF!	7.007088716
19.5	0.88131126	106.9659648	0.008239175	631.6413264	#REF!	7.536201462
20	0.899671912	114.8441848	0.007833848	657.5089507	#REF!	8.091255144
20.5	0.918032563	123.099367	0.007457655	683.7346562	#REF!	8.672867404
21	0.936393214	131.7402781	0.007107873	710.3135378	#REF!	9.281655883
21.5	0.954753865	140.7756847	0.006782094	737.2408869	#REF!	9.918238221
22	0.973114517	150.2143532	0.006478173	764.5121784	#REF!	10.58323206
22.5	0.991475168	160.0650503	0.006194201	792.123059	#REF!	11.27725504
23	1.009835819	170.3365426	0.005928474	820.0693373	#REF!	12.00092481
23.5	1.02819647	181.0375965	0.005679464	848.3469736	#REF!	12.75485901
24	1.046557122	192.1769787	0.005445799	876.952071	#REF!	13.53967527
24.5	1.064917773	203.7634558	0.005226245	905.8808675	#REF!	14.35599123
25	1.083278424	215.8057942	0.005019691	935.1297281	#REF!	15.20442455
25.5	1.101639075	228.3127605	0.004825131	964.6951381	#REF!	16.08559286
26	1.119999727	241.2931214	0.004641656	994.5736965	#REF!	17.0001138
26.5	1.138360378	254.7556434	0.00446844	1024.76211	#REF!	17.94860501
27	1.156721029	268.7090931	0.004304733	1055.257188	#REF!	18.93168414
27.5	1.17508168	283.1622369	0.004149853	1086.055836	#REF!	19.94996883
28	1.193442332	298.1238416	0.004003176	1117.155052	#REF!	21.00407671
28.5	1.211802983	313.6026735	0.003864135	1148.551923	#REF!	22.09462544
29	1.230163634	329.6074994	0.003732208	1180.243618	#REF!	23.22223264
29.5	1.248524285	346.1470858	0.003606918	1212.227385	#REF!	24.38751596
30	1.266884937	363.2301992	0.003487829	1244.50055	#REF!	25.59109305
30.5	1.285245588	380.8656063	0.003374538	1277.060511	#REF!	26.83358154
31	1.303606239	399.0620735	0.003266675	1309.904734	#REF!	28.11559908
31.5	1.32196689	417.8283674	0.003163899	1343.030753	#REF!	29.4377633
32	1.340327542	437.1732547	0.003065896	1376.436165	#REF!	30.80069185
32.5	1.358688193	457.1055018	0.002972373	1410.118626	#REF!	32.20500237
33	1.377048844	477.6338753	0.002883064	1444.075852	#REF!	33.65131251
33.5	1.395409495	498.7671419	0.002797717	1478.305616	#REF!	35.14023989
34	1.413770147	520.514068	0.002716104	1512.805742	#REF!	36.67240217
34.5	1.432130798	542.8834202	0.002638008	1547.574106	#REF!	38.24841698
35	1.450491449	565.8839652	0.002563231	1582.608636	#REF!	39.86890197
35.5	1.4688521	589.5244694	0.002491588	1617.907304	#REF!	41.53447478
36	1.487212752	613.8136994	0.002422906	1653.468131	#REF!	43.24575305
36.5	1.505573403	638.7604218	0.002357024	1689.289181	#REF!	45.00335441
37	1.523934054	664.3734032	0.002293791	1725.368559	#REF!	46.80789652
37.5	1.542294705	690.6614101	0.002233069	1761.704412	#REF!	48.65999701
38	1.560655357	717.6332091	0.002174726	1798.294928	#REF!	50.56027353
38.5	1.579016008	745.2975667	0.002118638	1835.138331	#REF!	52.50934371
39	1.597376659	773.6632496	0.002064692	1872.232883	#REF!	54.5078252
39.5	1.61573731	802.7390242	0.00201278	1909.576881	#REF!	56.55633564
40	1.634097962	832.5336572	0.001962801	1947.168657	#REF!	58.65549266
40.5	1.652458613	863.0559151	0.00191466	1985.006574	#REF!	60.80591392
41	1.670819264	894.3145645	0.001868268	2023.08903	#REF!	63.00821705
41.5	1.689179916	926.3183719	0.001823541	2061.414453	#REF!	65.2630197
42	1.707540567	959.0761039	0.001780402	2099.981301	#REF!	67.5709395
42.5	1.725901218	992.5965271	0.001738774	2138.788061	#REF!	69.93259409
43	1.744261869	1026.888408	0.00169859	2177.833248	#REF!	72.34860112
43.5	1.762622521	1061.960513	0.001659782	2217.115404	#REF!	74.81957824
44	1.780983172	1097.821609	0.001622288	2256.633099	#REF!	77.34614307
44.5	1.799343823	1134.480463	0.001586051	2296.384928	#REF!	79.92891326
45	1.817704474	1171.945841	0.001551014	2336.369511	#REF!	82.56850646







	Magnitude	Unit	
Geometric Dimensions	-	-	
Length	0.342	m	
Wing Chord Length	0.342	m	
S	0.008526676	m2	Area (flying squirrels have a square shaped wing)
% of wing evolved	27%		
Wing Span	0.09234	m	(MODIFY WING SPAN TO ALTER WING AREA)
Squirrel Weight	0.35	kg	
S_{WET}	0.017053351	m^2	Wetted area
Enviroment (Std.Sea Level)			
Density	1.225	kg/m^3	
Free Stream Velocity		m/s	
Dynamic Viscosity	1.79E-05	Pascal*s	
Temperature	288.15	K	
Pressure	101.325	kPa	
g	9.807	m/s^2	
Aerodynamics			
FLIGHT CONDITION			
Altitude (launch height in ft)	22.96588	ft	
Airspeed (KTAS)	10.2	Knots	
Airspeed	17.2176	ft/s	
Mach Number	0.015425034		
Density ratio	0.999328117		
Air density	0.002376402	$slugs/ft^3$	
Outside Air Temperature	518.6180951	°R	
Viscosity (Sutherland's formula)	3.74437E-07	lbf·s/ft	
Reynolds Number (Re)	3992840.254		
Launch Height	7	m	
Launch Velocity (V0)	5.25	m/s	
Launch Acceleration	0.3	m/s^2	
Launch Force	0.105	kg*m / s^2	
Lift			
Max L/D			
MAX glide	0	m	
iw	0	deg	Incidence of the wing
α_{0L}	-4.5	deg	
a_0	0.111	/deg	
e_w	1	-	span efficiency of the wing
AR	1	-	Aspect ratio — CAUSE OF LOW CL
λw	0	-	Taper ratio
a_w	0.036721303	/ deg	Clalpha of squirrel
CL0	0.165245861		Zero lift coefficient
Drag			
C_{dmisc}	0.006	-	Miscellaneous drag
Location of maximum thickness ((x/c)max)	0.5		
Thickness ratio (t/c)	0.15		
Skin friction coeffcient	0.003539772		ASSUMPTION
Interference Factor	1		
Form Factor	0.778235851		
Max thickness sweep angle	0		
Induced drag constant (K)	0.318309886		VERY HIGH
$C_{dmin\ i}$	0.161538792		Minimum drag coefficient
Range			
Range	7.296324326	m	

$$c_f = \frac{0.074}{Re^{0.2}}$$

NOTES

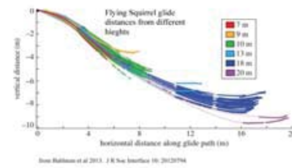
The Liebeck aerofoil (C_L = 3.06 and C_D = 0.005), close example of the aerodynamics of Glaucomys sabrinus

From Equation (1.45),

$$C_L = \frac{2W}{\rho_\infty V_\infty^2 S}$$

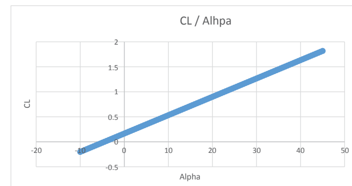
$$C_{L\alpha} = \frac{2\pi}{\left(1+\frac{2}{AR}\right)}$$

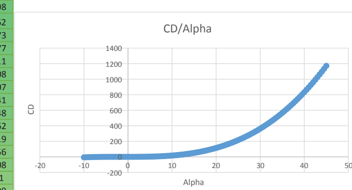
27% Modified

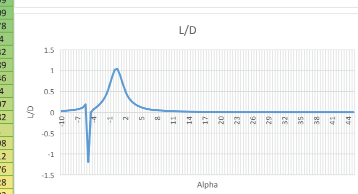


LIFT GENERATED BY WING

α	CL/Alpha	CD/Alpha	L/D	Sink Rate (m)	Lift (lb)	Drag (lb)
-10	-0.20197	-6.26728	0.032226	#NUM!	-0.019207893	-0.596043222
-9.5	-0.18361	-5.11301	0.03591	#NUM!	-0.017461721	-0.486268015
-9	-0.16525	-4.09901	0.040314	#NUM!	-0.015715549	-0.389832581
-8.5	-0.14689	-3.21651	0.045666	#NUM!	-0.013969376	-0.305903183
-8	-0.12852	-2.45674	0.052315	#NUM!	-0.012223204	-0.233646085
-7.5	-0.11016	-1.81094	0.060832	#NUM!	-0.010477032	-0.172227551
-7	-0.0918	-1.27033	0.072267	#NUM!	-0.00873086	-0.120813847
-6.5	-0.07344	-0.82616	0.088896	#NUM!	-0.006984688	-0.078571236
-6	-0.05508	-0.46965	0.117282	#NUM!	-0.005238516	-0.044665982
-5.5	-0.03672	-0.19205	0.191211	#NUM!	-0.003492344	-0.01826435
-5	-0.01836	0.015429	-1.18998	#NUM!	-0.001746172	0.001467396
-4.5	0	0.161539	0	#DIV/0!	0	0.015362991
-4	0.018361	0.255049	0.071989	431.0654504	0.001746172	0.024256173
-3.5	0.036721	0.304726	0.120506	182.0893087	0.003492344	0.028980675
-3	0.055082	0.319337	0.172488	103.8693008	0.005238516	0.030370235
-2.5	0.073443	0.307648	0.238723	64.99565196	0.006984688	0.029258587
-2	0.091803	0.278426	0.329722	42.08963787	0.00873086	0.026479468
-1.5	0.110164	0.240438	0.45818	27.65004918	0.010477032	0.022866613
-1	0.128525	0.202449	0.634848	18.47521041	0.012223204	0.019253758
-0.5	0.146885	0.173228	0.847932	12.93903439	0.013969376	0.016474639
0	0.165246	0.161539	1.022948	10.11190456	0.015715549	0.015362991
0.5	0.183607	0.17615	1.042332	9.414600312	0.017461721	0.016752551
1	0.201967	0.225827	0.894345	10.46180478	0.019207893	0.021477053
1.5	0.220328	0.319337	0.689954	12.9836626	0.020954065	0.030370235
2	0.238688	0.465446	0.512816	16.78319073	0.022700237	0.04426583
2.5	0.257049	0.672922	0.38199	21.71162935	0.024446409	0.063997576
3	0.27541	0.95053	0.289743	27.65340925	0.026192581	0.090399208
3.5	0.29377	1.307037	0.224761	34.51657431	0.027938753	0.124304462
4	0.312131	1.751209	0.178237	42.22644935	0.029684925	0.166547073
4.5	0.330492	2.291814	0.144205	50.7213183	0.031431097	0.217960777
5	0.348852	2.937618	0.118753	59.9493919	0.033177269	0.279379311
5.5	0.367213	3.697387	0.099317	69.8666282	0.034923441	0.351636408
6	0.385574	4.579888	0.084188	80.43513207	0.036669613	0.435565807
6.5	0.403934	5.593887	0.07221	91.62195761	0.038415785	0.532001241
7	0.422295	6.748151	0.062579	103.3981964	0.040161957	0.641776448
7.5	0.440656	8.051447	0.05473	115.7382731	0.041908129	0.765725162
8	0.459016	9.512542	0.048254	128.6193931	0.043654302	0.904681119
8.5	0.477377	11.1402	0.042852	142.0211047	0.045400474	1.059478056
9	0.495738	12.94319	0.038301	155.9249472	0.047146646	1.230949708
9.5	0.514098	14.93028	0.034433	170.314166	0.048892818	1.41992981
10	0.532459	17.11023	0.031119	185.1734789	0.05063899	1.627252099
10.5	0.55082	19.49182	0.028259	200.4888832	0.052385162	1.853750309
11	0.56918	22.0838	0.025774	216.2474953	0.054131334	2.100258178
11.5	0.587541	24.89494	0.023601	232.4374155	0.055877506	2.36760944
12	0.605901	27.93402	0.02169	249.0476141	0.057623678	2.656637832
12.5	0.624262	31.20979	0.020002	266.0678346	0.05936985	2.968177089
13	0.642623	34.73103	0.018503	283.488511	0.061116022	3.303060946
13.5	0.660983	38.5065	0.017166	301.3006959	0.062862194	3.66212314
14	0.679344	42.54496	0.015968	319.4959988	0.064608366	4.046197407
14.5	0.697705	46.85519	0.014891	338.0665328	0.066354538	4.456117482
15	0.716065	51.44595	0.013919	357.0048672	0.06810071	4.8927171
15.5	0.734426	56.326	0.013039	376.3039867	0.069846882	5.356829998
16	0.752787	61.50412	0.01224	395.9572546	0.071593055	5.849289912
16.5	0.771147	66.98907	0.011512	415.9583812	0.073339227	6.370930576
17	0.789508	72.78961	0.010846	436.301395	0.075085399	6.922585728
17.5	0.807869	78.91452	0.010237	456.9806175	0.076831571	7.505089102
18	0.826229	85.37255	0.009678	477.9906403	0.078577743	8.119274434
18.5	0.84459	92.17249	0.009163	499.3263046	0.080323915	8.76597546
19	0.862951	99.32308	0.008688	520.9826833	0.082070087	9.446025916
19.5	0.881311	106.8331	0.008249	542.9550641	0.083816259	10.16025954
20	0.899672	114.7113	0.007843	565.238935	0.085562431	10.90951006
20.5	0.918033	122.9665	0.007466	587.8299699	0.087308603	11.69461122
21	0.936393	131.6074	0.007115	610.7240174	0.089054775	12.51639675
21.5	0.954754	140.6428	0.006789	633.9170885	0.090800947	13.3757004
22	0.973115	150.0815	0.006484	657.4053472	0.092547119	14.27335588
22.5	0.991475	159.9322	0.006199	681.1851004	0.094293291	15.21019695
23	1.009836	170.2037	0.005933	705.2527899	0.096039463	16.18705733
23.5	1.028196	180.9047	0.005684	729.6049842	0.097785635	17.20477076
24	1.046557	192.0441	0.00545	754.2383712	0.099531807	18.26417098
24.5	1.064918	203.6306	0.00523	779.1497514	0.10127798	19.36609172
25	1.083278	215.6729	0.005023	804.3360321	0.103024152	20.51136673
25.5	1.101639	228.1799	0.004828	829.7942211	0.104770324	21.70082972
26	1.12	241.1603	0.004644	855.5214219	0.106516496	22.93531445
26.5	1.13836	254.6228	0.004471	881.5148285	0.108262668	24.21565464
27	1.156721	268.5762	0.004307	907.7717207	0.11000884	25.54268404
27.5	1.175082	283.0294	0.004152	934.2894601	0.111755012	26.91723637
28	1.193442	297.991	0.004005	961.0654859	0.113501184	28.34014537
28.5	1.211803	313.4698	0.003866	988.0973113	0.115247356	29.81224479
29	1.230164	329.4746	0.003734	1015.38252	0.116993528	31.33436835
29.5	1.248524	346.0142	0.003608	1042.918763	0.1187397	32.90734978
30	1.266885	363.0973	0.003489	1070.703755	0.120485872	34.53202284
30.5	1.285246	380.7327	0.003376	1098.735273	0.122232044	36.20922125
31	1.303606	398.9292	0.003268	1127.011151	0.123978216	37.93977874
31.5	1.321967	417.6955	0.003165	1155.529281	0.125724388	39.72452906
32	1.340328	437.0404	0.003067	1184.287608	0.12747056	41.56430594
32.5	1.358688	456.9726	0.002973	1213.284128	0.129216733	43.45994311
33	1.377049	477.501	0.002884	1242.516887	0.130962905	45.41227431
33.5	1.395409	498.6343	0.002798	1271.983977	0.132709077	47.42213328
34	1.41377	520.3812	0.002717	1301.683539	0.134455249	49.49035375
34.5	1.432131	542.7506	0.002639	1331.613753	0.136201421	51.61776946
35	1.450491	565.7511	0.002564	1361.772845	0.137947593	53.80521415
35.5	1.468852	589.3916	0.002492	1392.159079	0.139693765	56.05352154
36	1.487213	613.6808	0.002423	1422.770759	0.141439937	58.36352538
36.5	1.505573	638.6276	0.002358	1453.606227	0.143186109	60.7360594
37	1.523934	664.2405	0.002294	1484.663861	0.144932281	63.17195733
37.5	1.542295	690.5285	0.002233	1515.942071	0.146678453	65.67205292
38	1.560655	717.5003	0.002175	1547.439305	0.148424625	68.2371799
38.5	1.579016	745.1647	0.002119	1579.154041	0.150170797	70.868172
39	1.597377	773.5304	0.002065	1611.084789	0.151916969	73.56586295
39.5	1.615737	802.6062	0.002013	1643.230088	0.153663141	76.33108651
40	1.634098	832.4008	0.001963	1675.588508	0.155409313	79.1646764
40.5	1.652459	862.9231	0.001915	1708.158648	0.157155486	82.06746635
41	1.670819	894.1817	0.001869	1740.939131	0.158901658	85.0402901
41.5	1.68918	926.1855	0.001824	1773.928609	0.16064783	88.0839814
42	1.707541	958.9432	0.001781	1807.12576	0.162394002	91.19937396
42.5	1.725901	992.4637	0.001739	1840.529285	0.164140174	94.38730154
43	1.744262	1026.756	0.001699	1874.137912	0.165886346	97.64859786
43.5	1.762623	1061.828	0.00166	1907.950388	0.167632518	100.9840967
44	1.780983	1097.689	0.001622	1941.965487	0.16937869	104.3946317
44.5	1.799344	1134.348	0.001586	1976.182003	0.171124862	107.8810367
45	1.817704	1171.813	0.001551	2010.598751	0.172871034	111.4441453







	Magnitude	Unit	
Geometric Dimensions	-	-	
Length	0.342	m	
Wing Chord Length	0.342	m	
S	0.01052676	m2	Area (flying squirrels have a square shaped wing)
% of wing evolved	30%		
Wing Span	0.1026	m	(MODIFY WING SPAN TO ALTER WING AREA)
Squirrel Weight	0.33	kg	
S_{WET}	0.02105352	m^2	Wetted area
Enviroment (Std.Sea Level)			
Density	1.225	kg/m^3	
Free Stream Velocity		m/s	
Dynamic Viscosity	1.79E-05	Pascal*s	
Temperature	288.15	K	
Pressure	101.325	kPa	
g	9.807	m/s^2	
Aerodynamics			
FLIGHT CONDITION			
Altitude (launch height in ft)	22.96588	ft	
Airspeed (KTAS)	10.2	Knots	
Airspeed	17.2176	ft/s	
Mach Number	0.015425034		
Density ratio	0.999328117		
Air density	0.002376402	$slugs/ft^3$	
Outside Air Temperature	518.6180951	°R	
Viscosity (Sutherland's formula)	3.74437E-07	lbf·s/ft	
Reynolds Number (Re)	3992840.254		
Launch Height	7	m	
Launch Velocity (V0)	5.25	m/s	
Launch Acceleration	0.3	m/s^2	
Launch Force	0.099	kg*m / s^2	
Lift			
Max L/D			
MAX glide	0	m	
iw	0	deg	Incidence of the wing
α_{0L}	-4.5	deg	
a_0	0.111	/deg	
e_w	1	-	span efficiency of the wing
AR	1	-	Aspect ratio — CAUSE OF LOW CL
λw	0	-	Taper ratio
a_w	0.036721303	/ deg	Clalpha of squirrel
CL0	0.165245861		Zero lift coefficient
Drag			
C_{dmisc}	0.006	-	Miscellaneous drag
Location of maximum thickness ((x/c)max)	0.5		
Thickness ratio (t/c)	0.15		
Skin friction coeffcient	0.003539772		ASSUMPTION
Interference Factor	1		
Form Factor	0.778235851		
Max thickness sweep angle	0		
Induced drag constant (K)	0.318309886		VERY HIGH
$C_{dmin\ i}$	0.130846421		Minimum drag coefficient
Range			
Range	8.835892236	m	

$$c_f = \frac{0.074}{Re^{0.2}}$$

NOTES

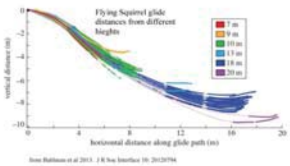
The Liebeck aerofoil (C_L = 3.06 and C_D = 0.005), close example of the aerodynamics of Glaucomys sabrinus

From Equation (1.45),

$$C_L = \frac{2W}{\rho_\infty V_\infty^2 S}$$

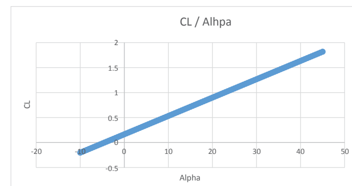
$$C_{L\alpha} = \frac{2\pi}{\left(1+\frac{2}{AR}\right)}$$

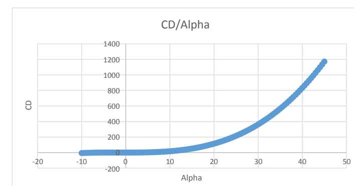
30% Modified

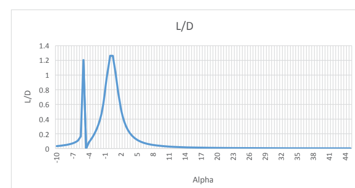


LIFT GENERATED BY WING

α	CL/Alpha	CD/Alpha	L/D	Sink Rate (m)	Lift (lb)	Drag (lb)
-10	-0.20197	-6.29797	0.032069	#NUM!	-0.021342103	-0.665513545
-9.5	-0.18361	-5.1437	0.035695	#NUM!	-0.019401912	-0.543541093
-9	-0.16525	-4.1297	0.040014	#NUM!	-0.017461721	-0.43639061
-8.5	-0.14689	-3.2472	0.045234	#NUM!	-0.015521529	-0.343135723
-8	-0.12852	-2.48743	0.05167	#NUM!	-0.013581338	-0.262850059
-7.5	-0.11016	-1.84163	0.059819	#NUM!	-0.011641147	-0.194607244
-7	-0.0918	-1.30103	0.070562	#NUM!	-0.009700956	-0.137480906
-6.5	-0.07344	-0.85685	0.085712	#NUM!	-0.007760765	-0.090544672
-6	-0.05508	-0.50035	0.110088	#NUM!	-0.005820574	-0.052872167
-5.5	-0.03672	-0.22274	0.164863	#NUM!	-0.003880382	-0.023537021
-5	-0.01836	-0.01526	1.202952	#NUM!	-0.001940191	-0.001612859
-4.5	0	0.130846	0	#DIV/0!	0	0.013826692
-4	0.018361	0.224356	0.081837	359.7325289	0.001940191	0.023708005
-3.5	0.036721	0.274034	0.134003	155.3459937	0.003880382	0.028957452
-3	0.055082	0.288645	0.19083	89.06820469	0.005820574	0.030501407
-2.5	0.073443	0.276956	0.265178	55.50878143	0.007760765	0.029266243
-2	0.091803	0.247734	0.370572	35.52807564	0.009700956	0.026178333
-1.5	0.110164	0.209746	0.525227	22.882683	0.011641147	0.02216405
-1	0.128525	0.171757	0.748293	14.86992184	0.013581338	0.018149766
-0.5	0.146885	0.142535	1.030519	10.1001593	0.015521529	0.015061856
0	0.165246	0.130846	1.262899	7.770325927	0.017461721	0.013826692
0.5	0.183607	0.145457	1.26227	7.375251962	0.019401912	0.015370647
1	0.201967	0.195135	1.035015	8.576030766	0.021342103	0.020620095
1.5	0.220328	0.288645	0.763319	11.13352559	0.023282294	0.030501407
2	0.238688	0.434754	0.54902	14.8720119	0.025222485	0.045940958
2.5	0.257049	0.642229	0.400245	19.65799747	0.027162677	0.06786512
3	0.27541	0.919837	0.299411	25.38722747	0.029102868	0.097200267
3.5	0.29377	1.276344	0.230166	31.97635905	0.031043059	0.134872771
4	0.312131	1.720517	0.181417	39.35742849	0.03298325	0.181809005
4.5	0.330492	2.261122	0.146163	47.4740567	0.034923441	0.238935343
5	0.348852	2.906925	0.120007	56.27877515	0.036863632	0.307178158
5.5	0.367213	3.666694	0.100148	65.73109566	0.038803824	0.387463822
6	0.385574	4.549195	0.084756	75.79608767	0.040744015	0.480718709
6.5	0.403934	5.563195	0.072608	86.44330967	0.042684206	0.587869192
7	0.422295	6.717459	0.062865	97.64599309	0.044624397	0.709841644
7.5	0.440656	8.020755	0.054939	109.3804095	0.046564588	0.847562437
8	0.459016	9.481849	0.04841	121.6253735	0.048504779	1.001957946
8.5	0.477377	11.10951	0.04297	134.3618469	0.050444971	1.173954542
9	0.495738	12.9125	0.038392	147.5726203	0.052385162	1.364478599
9.5	0.514098	14.89959	0.034504	161.2420545	0.054325353	1.574456491
10	0.532459	17.07954	0.031175	175.3558676	0.056265544	1.804814589
10.5	0.55082	19.46112	0.028304	189.9009599	0.058205735	2.056479268
11	0.56918	22.0531	0.02581	204.8652662	0.060145927	2.3303769
11.5	0.587541	24.86425	0.02363	220.2376331	0.062086118	2.627433858
12	0.605901	27.90333	0.021714	236.0077143	0.064026309	2.948576515
12.5	0.624262	31.1791	0.020022	252.1658815	0.0659665	3.294731245
13	0.642623	34.70034	0.018519	268.7031483	0.067906691	3.66682442
13.5	0.660983	38.4758	0.017179	285.6111042	0.069846882	4.065782413
14	0.679344	42.51427	0.015979	302.881858	0.071787074	4.492531599
14.5	0.697705	46.82449	0.0149	320.5079877	0.073727265	4.947998348
15	0.716065	51.41525	0.013927	338.4824975	0.075667456	5.433109035
15.5	0.734426	56.29531	0.013046	356.7987794	0.077607647	5.948790033
16	0.752787	61.47343	0.012246	375.4505797	0.079547838	6.495967715
16.5	0.771147	66.95837	0.011517	394.4319692	0.08148803	7.075568453
17	0.789508	72.75892	0.010851	413.7373169	0.083428221	7.688518622
17.5	0.807869	78.88382	0.010241	433.3612658	0.085368412	8.335744593
18	0.826229	85.34186	0.009681	453.2987126	0.087308603	9.01817274
18.5	0.84459	92.14179	0.009166	473.544788	0.089248794	9.736729435
19	0.862951	99.29239	0.008691	494.09484	0.091188985	10.49234105
19.5	0.881311	106.8024	0.008252	514.9444187	0.093129177	11.28593397
20	0.899672	114.6806	0.007845	536.0892616	0.095069368	12.11843455
20.5	0.918033	122.9358	0.007468	557.5252818	0.097009559	12.99076917
21	0.936393	131.5767	0.007117	579.2485561	0.09894975	13.90386421
21.5	0.954754	140.6121	0.00679	601.2553141	0.100889941	14.85864603
22	0.973115	150.0508	0.006485	623.5419296	0.102830132	15.85604101
22.5	0.991475	159.9015	0.006201	646.1049107	0.104770324	16.89697553
23	1.009836	170.173	0.005934	668.9408927	0.106710515	17.98237595
23.5	1.028196	180.874	0.005685	692.0466299	0.108650706	19.11316866
24	1.046557	192.0134	0.00545	715.4189894	0.110590897	20.29028001
24.5	1.064918	203.5999	0.00523	739.0549445	0.112531088	21.51463639
25	1.083278	215.6422	0.005023	762.9515687	0.11447128	22.78716417
25.5	1.101639	228.1492	0.004829	787.1060309	0.116411471	24.10878973
26	1.12	241.1296	0.004645	811.5155897	0.118351662	25.48043942
26.5	1.13836	254.5921	0.004471	836.1775893	0.120291853	26.90303964
27	1.156721	268.5455	0.004307	861.089455	0.122232044	28.37751674
27.5	1.175082	282.9987	0.004152	886.248689	0.124172235	29.90479711
28	1.193442	297.9603	0.004005	911.652867	0.126112427	31.48580712
28.5	1.211803	313.4391	0.003866	937.2996345	0.128052618	33.12147313
29	1.230164	329.4439	0.003734	963.1867033	0.129992809	34.81272153
29.5	1.248524	345.9835	0.003609	989.3118491	0.131933	36.56047868
30	1.266885	363.0666	0.003489	1015.672908	0.133873191	38.36567097
30.5	1.285246	380.7021	0.003376	1042.267774	0.135813383	40.22922475
31	1.303606	398.8985	0.003268	1069.094396	0.137753574	42.15206641
31.5	1.321967	417.6648	0.003165	1096.150778	0.139693765	44.13512232
32	1.340328	437.0097	0.003067	1123.434972	0.141633956	46.17931885
32.5	1.358688	456.9419	0.002973	1150.94508	0.143574147	48.28558238
33	1.377049	477.4703	0.002884	1178.679251	0.145514338	50.45483927
33.5	1.395409	498.6036	0.002799	1206.635678	0.14745453	52.68801591
34	1.41377	520.3505	0.002717	1234.812598	0.149394721	54.98603865
34.5	1.432131	542.7199	0.002639	1263.208289	0.151334912	57.34983388
35	1.450491	565.7204	0.002564	1291.821068	0.153275103	59.78032798
35.5	1.468852	589.3609	0.002492	1320.649291	0.155215294	62.2784473
36	1.487213	613.6501	0.002424	1349.69135	0.157155486	64.84511823
36.5	1.505573	638.5969	0.002358	1378.945675	0.159095677	67.48126714
37	1.523934	664.2099	0.002294	1408.410727	0.161035868	70.1878204
37.5	1.542295	690.4979	0.002234	1438.085001	0.162976059	72.96570439
38	1.560655	717.4697	0.002175	1467.967026	0.16491625	75.81584548
38.5	1.579016	745.134	0.002119	1498.055358	0.166856441	78.73917003
39	1.597377	773.4997	0.002065	1528.348586	0.168796633	81.73660443
39.5	1.615737	802.5755	0.002013	1558.845325	0.170736824	84.80907505
40	1.634098	832.3701	0.001963	1589.54422	0.172677015	87.95750825
40.5	1.652459	862.8924	0.001915	1620.443941	0.174617206	91.18283042
41	1.670819	894.151	0.001869	1651.543186	0.176557397	94.48596793
41.5	1.68918	926.1548	0.001824	1682.840675	0.178497588	97.86784714
42	1.707541	958.9126	0.001781	1714.335154	0.18043778	101.3293944
42.5	1.725901	992.433	0.001739	1746.025394	0.182377971	104.8715362
43	1.744262	1026.725	0.001699	1777.910187	0.184318162	108.4951988
43.5	1.762623	1061.797	0.00166	1809.988347	0.186258353	112.2013086
44	1.780983	1097.658	0.001623	1842.25871	0.188198544	115.9907919
44.5	1.799344	1134.317	0.001586	1874.720134	0.190138736	119.8645752
45	1.817704	1171.782	0.001551	1907.371494	0.192078927	123.8235848

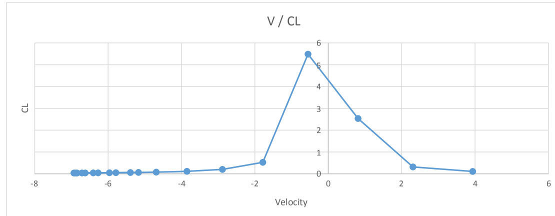




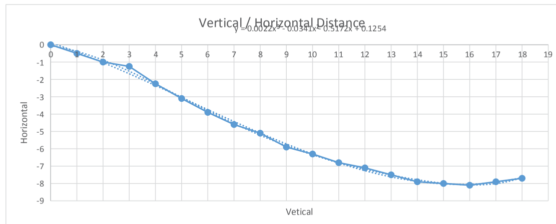


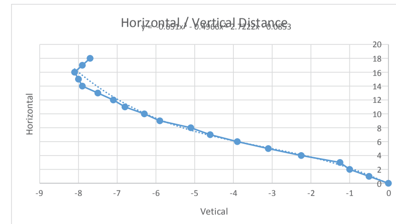
Horizontal Distance (m)	Vertical Distance (m)
0	0
1	-0.5
2	-1
3	-1.25
4	-2.25
5	-3.1
6	-3.9
7	-4.6
8	-5.1
9	-5.9
10	-6.3
11	-6.8
12	-7.1
13	-7.5
14	-7.9
15	-8
16	-8.1
17	-7.9
18	-7.7

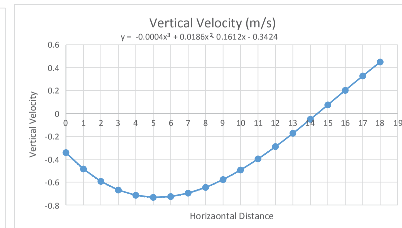
V (m/s)	CL
-5.172	0.062468
-5.788	0.049879
-6.272	0.042478
-6.624	0.038083
-6.844	0.035674
-6.932	0.034774
-6.888	0.03522
-6.712	0.037091
-6.404	0.040745
-5.964	0.046978
-5.392	0.057474
-4.688	0.076032
-3.852	0.112616
-2.884	0.200901
-1.784	0.525029
-0.552	5.483969
0.812	2.534318
2.308	0.313691
3.936	0.107861



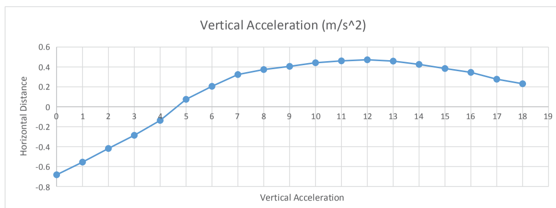
Horizontal Distance (m)	Vertical Velocity (m/s)
0	-0.3424
1	-0.4854
2	-0.5936
3	-0.6694
4	-0.7152
5	-0.7334
6	-0.7264
7	-0.6966
8	-0.6464
9	-0.5782
10	-0.4944
11	-0.3974
12	-0.2896
13	-0.1734
14	-0.0512
15	0.0746
16	0.2016
17	0.3274
18	0.4496







Horizontal Distance (m)	Vertical Acceleration (m/s^2)
0	-0.6822
1	-0.5552
2	-0.4182
3	-0.2861
4	-0.1365
5	0.0752
6	0.2058
7	0.324
8	0.374
9	0.406
10	0.4423
11	0.4611
12	0.4722
13	0.4587
14	0.4258
15	0.3845
16	0.3456
17	0.2771
18	0.2315



Horizontal Distance (m)	Horizontal Velocity (m/s)
0	-0.6822
1	-0.5552
2	-0.4182
3	-0.2861
4	-0.1365
5	0.0752
6	0.2058
7	0.324
8	0.374
9	0.406
10	0.4423
11	0.4611
12	0.4722
13	0.4587
14	0.4258
15	0.3845
16	0.3456
17	0.2771
18	0.2315