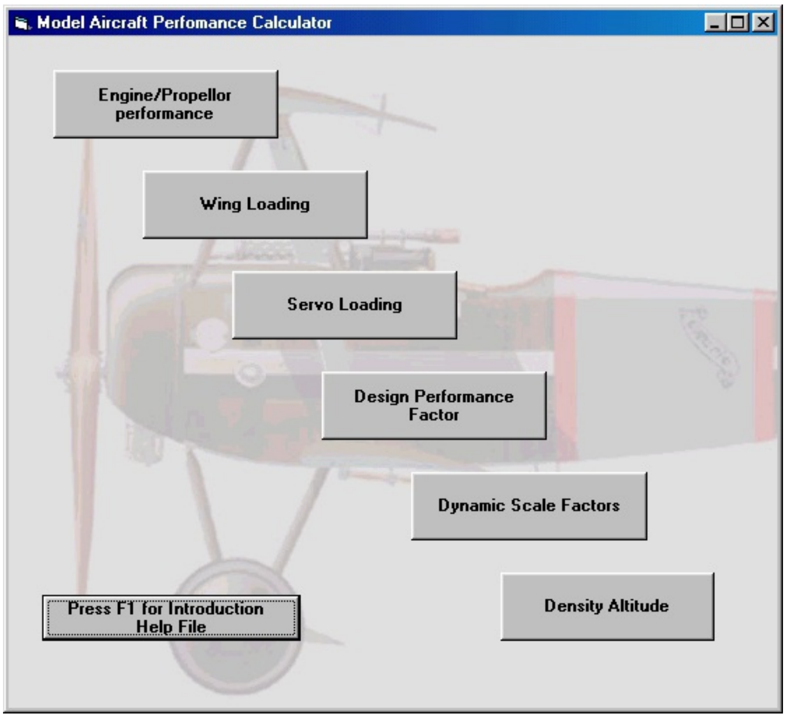
Model Aircraft Performance Calculator



Introduction

This is a graphics based claculator that will allow you to calculate parameters to assist in the design and performance of model aircraft.

-The graphic display's are navigated using the mouse pointer.
-The co-ordinates of the mouse pointer in the current graph, are displayed in text box's and update as the mouse pointer is moved.

-Left clicking on the graph or the appropriate command button, will calculate the required results.

-Right clicking the mouse button will clear the graph.

-Clicking the 'Print Screen" button will print a bitmap of the current display to your printer. (set the printer to "Landscape" mode for best results)

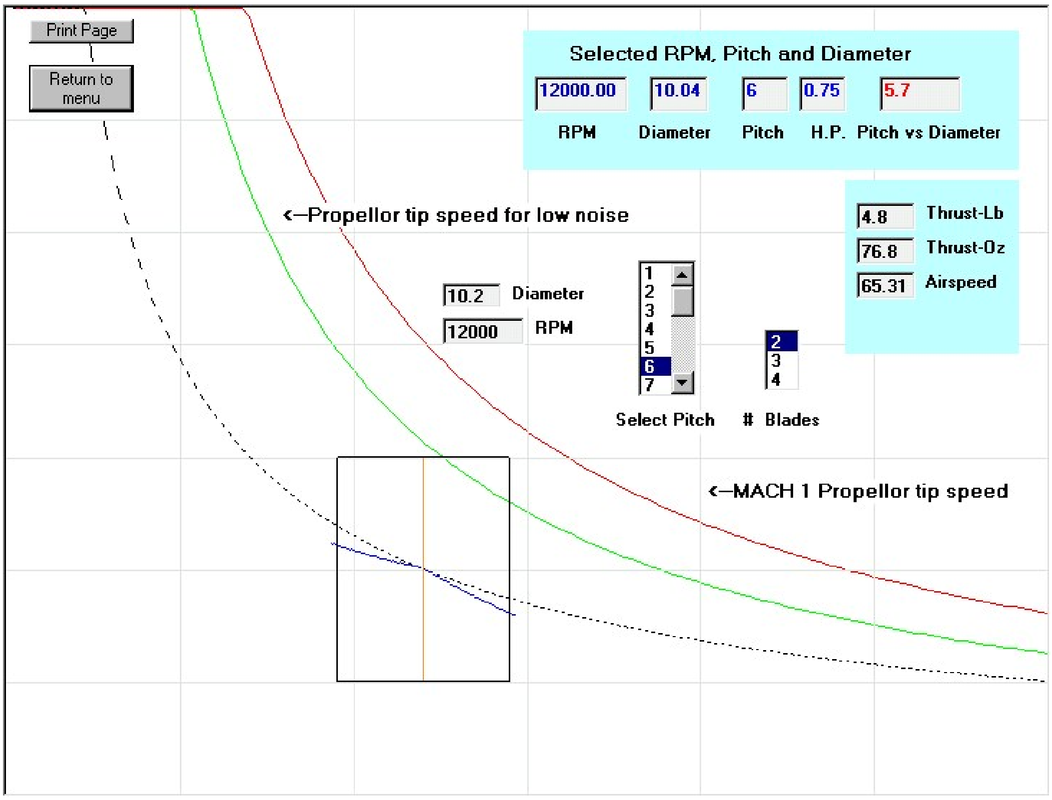
-Clicking the "Return to Menu" button will return to the Main Menu.

-Pressing the F1 button on your keyboard will display a context sensitive Help File.

Examples:

Putting it all together

Engine Performance.
Wing loading
Aircraft Performance Factor
Dynamic Scale Factors
Servo Torque
Density Altitude



Engine Performance

The initial page display's a graph whose axis are Propellor diameter(35 " Max) and Revolutions Per Minute(RPM)(30,000 Max).
The initial setting for propellor pitch is 6 ", to change the pitch move the pitch elevator button until the required pitch is displayed and click on the required pitch.

To change the number of propeller blades use the blade list box.

As the mouse pointer is moved around the graph a continous readout is calculated and displayed of; Propellor Diameter, RPM, Horsepower(BHP), Propellor thrust, and Airspeed capability

Determine the best operating characteristics for the engine under consideration. (See Section on BHP characteristics)

Operate the engine and measure the RPM, note the Diameter and Pitch of the propellor.(See Section on Pitch measurement, the pitch marked on the propellor is not necesarily the actual pitch)

Clicking on the graph at the required Diameter and RPM will display three lines on the graph .

The dotted **Black** line is a plot of RPM Vs Diameter for the calculated HP.

The **Blue** line is an estimation of the loss in HP if it is desired to operated the engine away from the maximum performance RPM. the propellor diameter/pitch combination is selected from the values indicated by the Blue line.

The **Red** line allows the selection of a propellor diameter/pitch combination that will absorb the same calculated HP to maintain the same RPM.

The graph also display's the propellor tip speed curves for Diameter/RPM combinations, the rule of thumb is 75% of Mach 1 for low noise.

Horsepower Example

Run the engine using the propeller recommended by the manufacturer. Or at a performance you like.
Measure the peak RPM, note the diameter and pitch of the propeller (the marked pitch may not be the actual pitch, see pitch measurement)

Select the value for the number of blades and pitch of the propeller using the list box's .(default is 2 blades, 6" pitch)

Move the mouse pointer until the values of rpm, diameter are correct. Click the left button.

The blue boxwill display the selected rpm diameter and pitch, and the calculated HP.

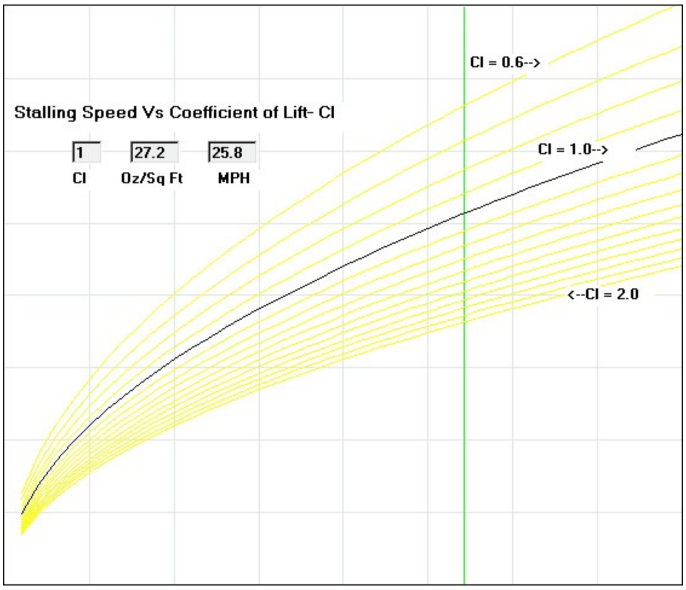
The red figures display a calculated pitch that corresponds to the red line drawn vertically at the selected point. This pitch value is the pitch value that combined with the value of the diameter shown by the mouse pointer will absorb the same power and rotate at the same rpm.
The calculations for thrust and airspeed are performed continuously.(blue box)

Move the pointer along the red line.

The airspeed calculation will change to a calculation using the pitch caculated as the mouse pointer is moved along the red line.

Select the airspeed and thrust that suits the airplane characteristics. Low airspeed, high thrust for trainers, WW 1 etc, High airspeed, lower thrust for high speed potential.

If possible refer to the published BHP curves for the best propeller for maximum BHP or torque.. (See the BHP section).



Wing Loading

The initial page display's a graph whose axis are weight(50# max.) and wing area(3000 Sq. in max.), also displayed are constant load lines for various wing loading (black) and the wing volume loading curves (Blue) for various wing volume loadings.

Move the mouse pointer to the wing area and weight desired, click the left mouse button.
A graph will be displayed that plots the stalling speed, for the wing loading selected, at various coefficients of lift(Cl)(See the Section on Cl).

The green line is the selected wing loading

The Wing volume loading is also calculated. (See the Aircraft Performance Factor Graph)

Right click the mouse in the initial graph, to clear the second graph.

Wing Loading and Stalling speed

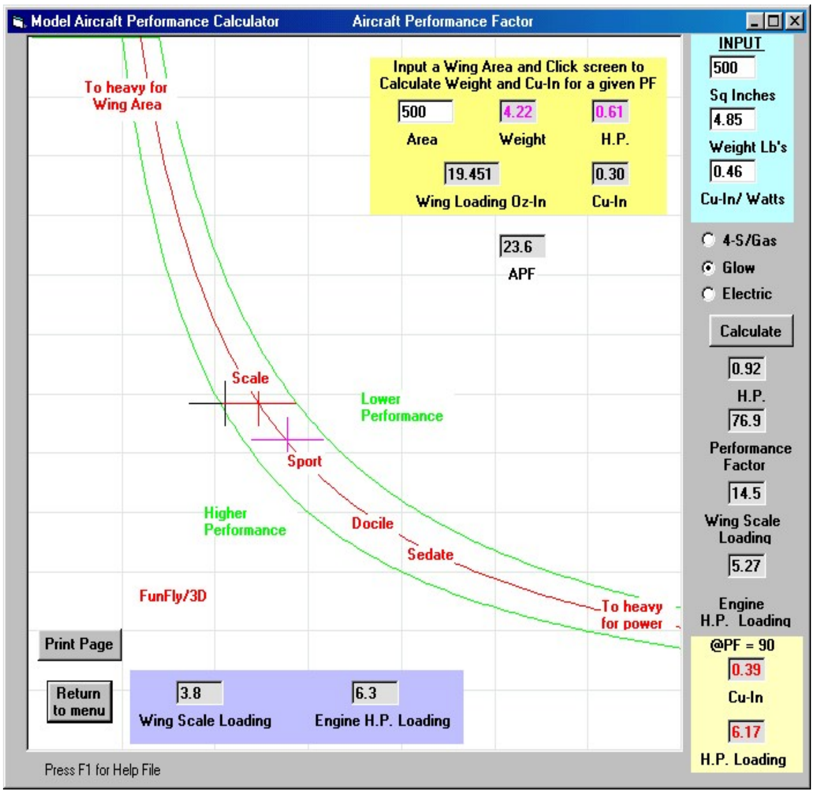
Measure the wingspan and the average chord of the wing in inches. Wing area = (Wingspan x Chord) sq-in

Move the mouse pointer until the weight and wing area box's show the desired values.

Click the left mouse button.

A new graph will display the stalling speed curves for various values of Cl. The green line is the calculated wing loading for the values selected.(See the Section on Cl).

The Wing volume loading is also calculated. (See the Aircraft Performance Factor Graph



Aircraft Performance factor(APF)

It can be seen that different combinations of wing area, weight and power can produce airplanes with with drastically different performances.

The display's is a graph whose axis are Wing Scale Loading (Weight per Wing volume loading) and Horse Power Loading(Pounds per HP), also displayed are constant APF lines for three aircraft performance factors.

The concept is that you will need a certain amount of power to lift a given weight, and an appropriate amount of wing area to support that weight.

Input the values for your airplane and see where you fall?

From generally accepted practice and calculations based on the recent anlysis of multiple models that perform well and experience from those that do not perform well, a PF of 90 is a desirable goal. The sport label is positioned at the average of all the models analysed to create the performance curves (PF Graph)

The value for HP loading should always be less than than 12. That is <12 pounds per HP or >62 watts per pound

The characteristics of various types of models are noted

Will It Fly?

APF selection

Clicking anywhere on the graph will plot a magenta cross at the selected point, the weight and Cu-in displacement are calculated for the wing area input (Default is 500 Sq. in) in the yellow box.

-These would be the design requirements for the selected point

-Input further wing areas as required for further calculations.

APF calculations

Clicking on the "Calculate" Button will calculate the APF for the Inputs of wing area, weight and Cu-In, (Blue box), (Default values are 500sq in, 5 Lb and .46Cu-in) and when calculated is plotted as a Black cross on the graph,

At the same time the 'Calculate" button will also calculate the required weight and Cu-In for a APF of 100,(Lemon box), and is plotted as a Red cross on the graph.

Input wing area, weight and Cu-In as required for further calculations.

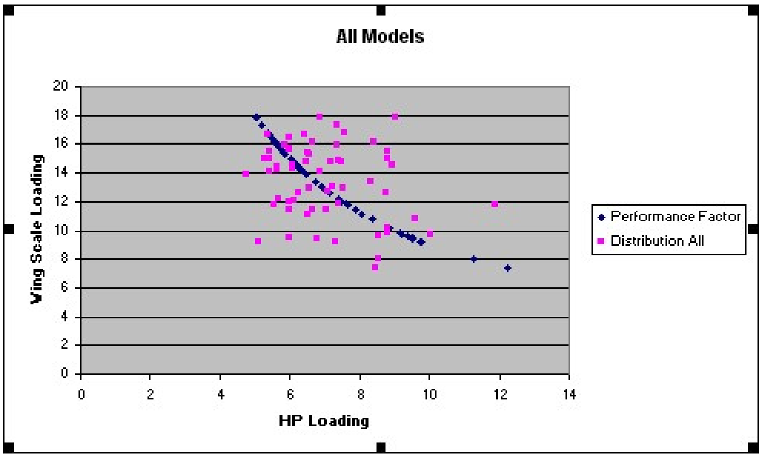
Theory

The Wing Scale loading is a method of acounting for the size to weight ratio changes in wing loading as the size (scale) of the model changes, and is calculated by dividing the weight of the model by the wing area multiplied by the square root of the wing area and adjusted for scale factor by raising to the .8 power.

The Horse Power Loading is the weight of the model divided by the H.P. of the engine. The value for the Horse Power loading should never be more than 12.

Ex: CGM Decathlon , 10 Lb, 1.8 Hp. HP loading = 5.56
Hangar Extra 330L , 25 Lb, 3.4 Hp. HP loading = 5.7

2 BHP has been assumed (average of published data) for one Cu-In of displacement for Two stroke (Methanol) engines , FourStroke's and Gas engines have been assumed (average of published data) to have 1.2 Hp per Cu-In. Electric motor wattage is based on 746 watts per horsepower.



Performance Factor Revisited

In 1989 Model Builder published an article by Francis Reynolds on concepts called “Wing Cube Loading”, “Cubic inch loading” and “Performance Factor”.

Modern models and their technology has made it worthwhile to revisit the subject

The concept of “Wing Cube Loading” is that by creating a formula that incorporates the square root of the wing area, that makes the formula a cubic equation. This avoids the problem of using just wing loading as a measure of performance, as wing loading should increase as the scale of the aircraft is increased.
This concept adjusts the calculations involving wing area to include the effects of aspect ratio and scale. This makes the calculation true for most sizes of aircraft. The exception will be modern fighter aircraft (P-51 For example)
The formula is described as
The weight of the aircraft divided by, the wing area, multiplied by the square root of the wing area.

Wing Cube Loading =

The Cubic Inch loading divides the weight of the aircraft by the cubic inch displacement of the engine(s)

Cubic Inch Loading

The Performance Factor is a constant that equals the Wing Cube loading multiplied by the by the Cubic Inch Loading. The constant will vary with the type of aircraft.

A large number of modern models were analyzed using a excel spreadsheet and plotted against various performance factors. It was noted that for today’s models the wing cube loading need to by adjusted and made slightly non linear, I have called this the Wing Scale factor. This is the Y-axis of the graph.

The publication of the BHP curves of modern engine has made it possible to now use BHP loading as the X-axis of the graph.
Analysis of the BHP data averages shows that a 2-stroke glow engine has approximately 2.0 BHP per Cubic Inch, 4-stroke and Gas engines have 1.2 BHP per cubic inch. This also normalizes the graph for all types of engines.

The appropriate performance factor constant for models based on the latest data is a value of 90; this is plotted in Fig 1 , shown are various types of models, the average for the distribution of the model data is a wing scale loading of 14, and a HP loading of 6.5. This is illustrated in fig 2.

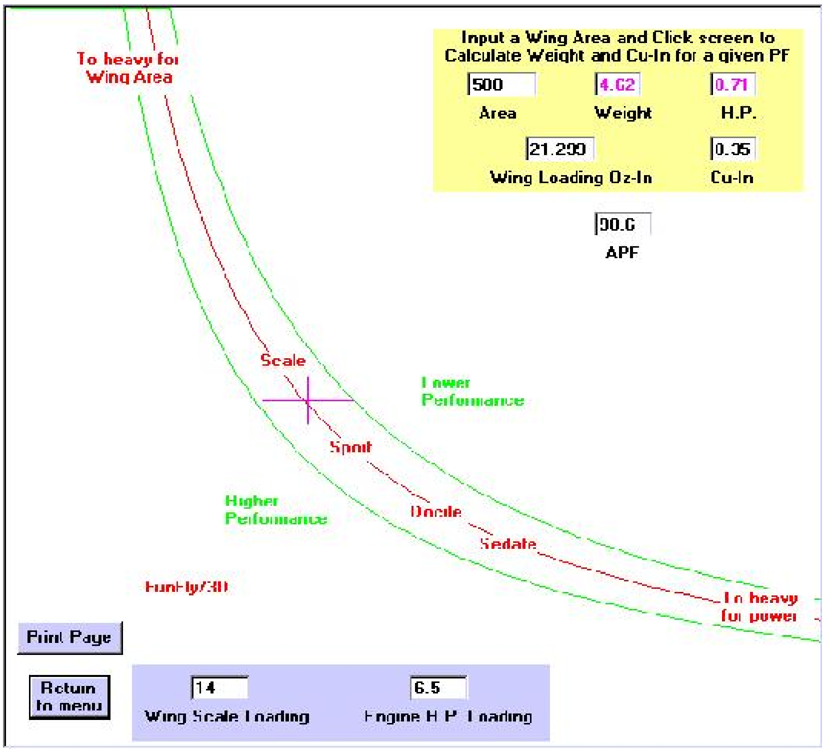


Fig 1 is taken from the Model Aircraft Performance Calculator software at www.printwares.com

Model data Analysis

The data is clustered about a value of 14 for the Wing Scale Factor and a value of 6.5 for the HP Loading factor.
The range of the data varies from a value of WSF of 16 to a HP loading of 12.

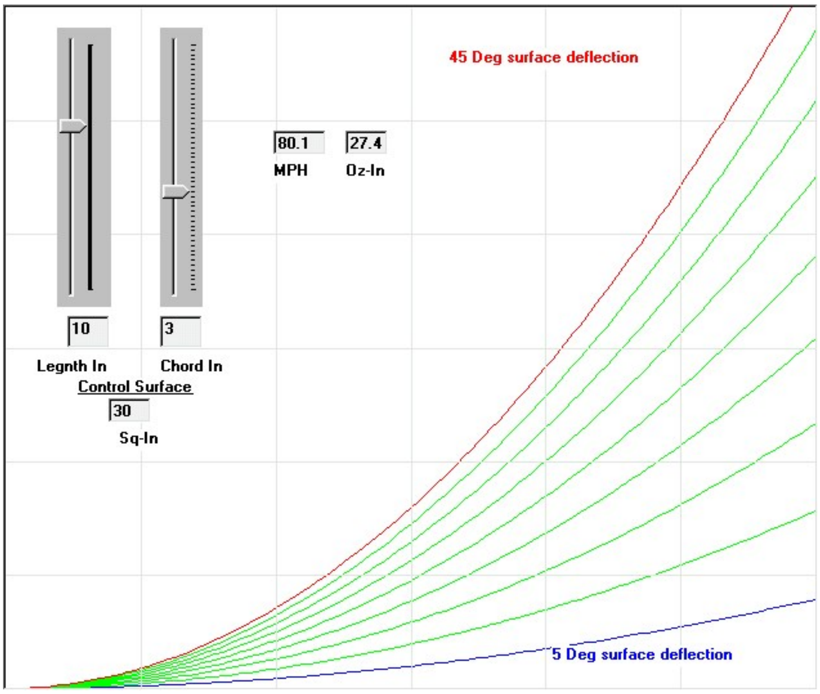
A HP loading of 10, that is 10Lb per HP or 20Lb per Cu In, would seem to be the lowest limit for a sedate performing model.

A HP loading of 5.5 would make a hot performing model if the wing scale factor loading is kept low.

Fun fly and 3-D capable models need a Wing scale loading of 7 and a HP laoding 0f 4

Thus the design values for acceptable performance, WSL=14, HPL=6.5, would be as follow for various wing areas.

Wing Area Sq In	Weight	HP/Glow Cu-In/4s-Gas Cu-In			Wing Loading
330	2.46	.38	.19	.23	17.2
500	4.59	.71	.35	.59	21.2
800	9.3	1.43	.71	1.19	26.8
1100	15	2.32	1.16	1.93	31.6
1500	24	3.69	1.84	3.0	36.9
2000	36.9	5.71	2.9	4.8	42.6



Servo Load

The initial page display's a graph whose axis are Torque in Oz/In and Airspeed in MPH, also displayed are Torque Vs Airspeed curves for different deflection angles(5 to 45 Deg) of the control surface.

As the mouse is moved the values for Oz-In and speed are displayed.

The vertical scroll bars change the inputs of the Chord and Length of the control surface, a calculation for control surface area is made and displayed.

As the control surface area is changed the torque velocity curves are replotted, note that the scale of the vertical axis change as needed.

Ex: 1/4 scale light plane. Aileron area 25 x 3 , scale speed 40 mph, surface deflection 30 Deg.
Required torque = 22 Oz-In
1/4 Scale fighter with the same size control surface and deflection and a scale speed of 120 mph
Required torque = 226 Oz in.

Reduce the Fighter control deflection to 5 deg,
Required torque = 38 Oz-In

Theory

The calculated results compare favorably to the practical test results results published in 1933 by NACA (Report #278), for a 18"x1.8" control surface at 40 mph.
20 Deg = 6.4 Oz-In
10 Deg = 3.2 Oz-In
5 Deg = 2 Oz in

And to practical test results published May 1998 in Model Airplane News(tm)

If the Ch values derived in NACA technical report 441 are applied the the "hinge moment" equation (Clark Y with sealed aileron) good agreement is also found.

Formulae for the torque load are theoretical, one that is based on the "hinge moment" equation follows;

H = 1/2*p*V^2*C^2*L*Ch (McCormick)

p = Air density
V = airspeed
C = chord
L = length
Ch = Coefficient of the hinge moment

Ch consists of three parts b1*a1 + b2*a2 + b3*a3

b1*a1 = the angle of attack of the control surface * hinge moment factor b1
b2*a2 = the angle of deflection of the control * hinge moment factor b2
b3*a3 = the angle of deflection of the trim tab * hinge moment factor b3

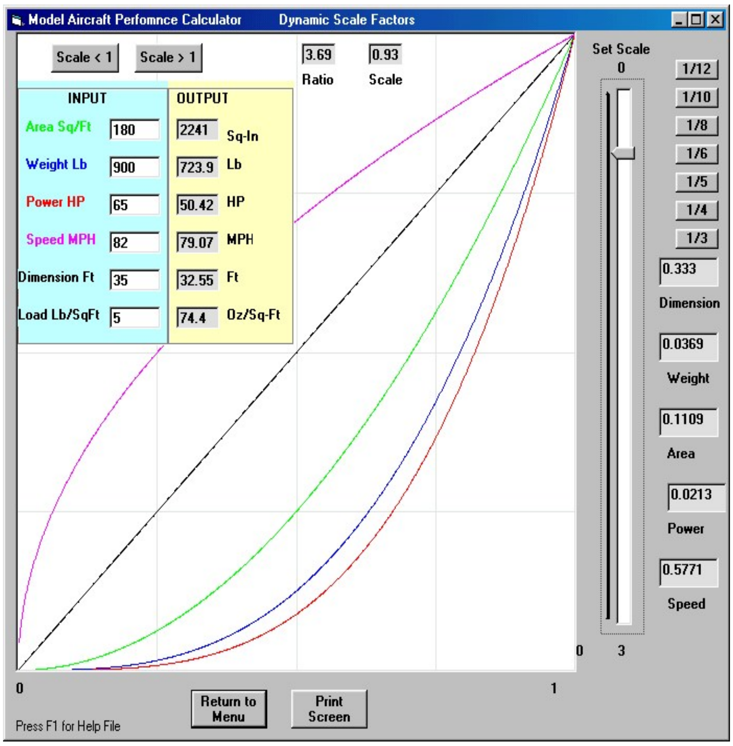
b2*a2 is the only parameter of interest for this program.

The value for torque;

Force = H/A, where A is approx 1/3 surface chord.

The formula used for this program is of the form conceived Craig Tenney and has been modified agree with measured results and comparisons to other methods of calculating servo toque;

Toque = ((Sin(Angle of surface deflection) (Chord-In) ^ 2 * Length-In * (mph) ^ 2)) * 0.0000085



Dynamic Scale Factors

The initial page display's a graph whose axis are Scale ratio and Scale Factor, also displayed are the graphs for Size, Wing Area Weight Power and Speed, at a default scale factor of less than 1. A button is provide for scale factors greater than 1.

The Scale vertical scroll bar has a default value of 1/3.

Preset button are provided for common scale factors

An input box is provided for data from an aircraft, the output boxes calculate the required values

Scale Effect

The object is to scale an existing design(larger or smaller) and have it fly in a manner similar to the original as far as the flight performance is concerned.
That is the scaled version would have the same "scaled" manouverability as the original.

From the examples below it can be seen that to model to exact scale can be very difficult

Mass(weight)

To make the mass density the same in the model as the original, then the mass is proportional to the volume,and thus equal to the cube of the scale factor.

Ex: Piper J-3 Cub, mass is 1000 pounds and a 36 Ft wingspan, a 1/6 scale model will weigh 4.6 pounds, a 1/4 scale cub would weigh 15.6 pounds.

This works for lightly loaded aircraft, modelling very high powered military aircraft is very difficult to model at scale speeds, a P-51 would work out to a wingloading of 80 Oz/Sq-Ft, To high for comfort. So a conservative scale factor here would be 1/2 of the scaled weight and 1/2 of scaled power.
(See Aircraft Performance Section)

Wing Loading

The wing area is changed by the square of the scale factor, and the weight is proportional to the cube of the scale factor. Then the wing loading will be proportional to the scale factor.

Changing Scale

The scale factors follow full size practice and are useful for scaleing a model up or down from

another size aircraft.

Scaling Down

NA P-51 D Mustang

Scale Factor	1	1/4	1/4@APF=90	1/5	1/5@APF=90	1/6	1/6@APF=90	1/10	1/6@APF=90
Wing Span	37 ft	111 in	111 in	89 in	89 in	74 in	74 in	44 in	44 in
Weight	7125 Lb	111 Lb	33 lb	57 Lb	16 Lb	33 lb	9.73 lb	7.1 lb	2 lb
Area	230 ft	2100 in	2100 in	1325 in	1325 in	927 in	927 in	333 in	333 in
Wing Loading	31 Lb	123 Oz	36 Oz	99 Oz	30 oz	82 oz	24 oz	49 oz	14 oz
Airspeed/Max	437 mph	218 mph	218 mph	196 mph	196 mph	179 mph	179 mph	135 mph	135 mph
Airspeed/cruise	250 mph		125 mph		111 mph		100 mph		79 mph
Power	1695 hp	13.2 hp	4.48 hp	6.1 hp	2.24 hp	3.2 hp	1.31 hp	0.61 hp	0.28

High power military aircraft are difficult to model at scale speeds. To model these, use the Aircraft Performance Factor page to estimate the appropriate weights and HP. As shown above. = Approx 1/2.. It would also be unrealistic to get the scale top speed at the reduced HP.

Piper J-3 Cub

Scale Factor	1	1/3	1/4	1/5	1/6	1/10
Wing Span	35 ft	140 in	105 in	84 in	70 in	42 in
Weight	900 lb	32.31 lb	14 lb	7.2 lb	4.2 lb	14 oz
Area	180 ft	2822 in	1600 in	1036 in	700 in	260 in
Wing Loading	5 lb	26.51 oz	20 oz	16 oz	13 oz	8 oz
Airspeed	82 mph	47 mph	41 mph	37 mph	34 mph	25 mph
Power	65 hp	1.33 hp	.51 hp	.23 hp	.12 hp	0.02 hp

This model would need more power to satisfy most modellers.

Douglas DC-3

Scale Factor	1	1/6	1/8	1/10	1/12
Wing Span	95 ft	190 in	142in	114 in	95 in
Weight	16289 lb	75 lb	31.8 lb	16.3 lb	9.4 lb
Area	990 ft	3840 in	2132 in	1421 in	852 in
Wing Loading	16.5	44 oz	32 oz	26 oz	22 oz
Airspeed	192 mph	79 mph	68 mph	61 mph	55
Power	850 hp	1.6 hp	.59 hp	0.26 hp	0.14

DC-3 needs a little more power

Bowers FLY BABY

Scale Factor	1	1/4	1/5	1/6	1/10
Wing Span	28 ft	84	67	56	34 in
Weight	900 lb	13.5 lb	7.2 lb	3.6 lb	14.4 oz
Area	126 ft	1124 in	725 in	490 in	181 in
Wing Loading	7.6 lb	30.4 oz	24.32 oz	20.26 oz	12.16 oz
Airspeed	100 mph	50 mph	44.7 mph	40.7 mph	31.6 mph
Power	65 hp	0.45 hp	0.234 hp	0.1235 hp	0.0195 hp

The flybaby will fly (sedately) with this power, but the modeller will prefer more power.

Scaling Up

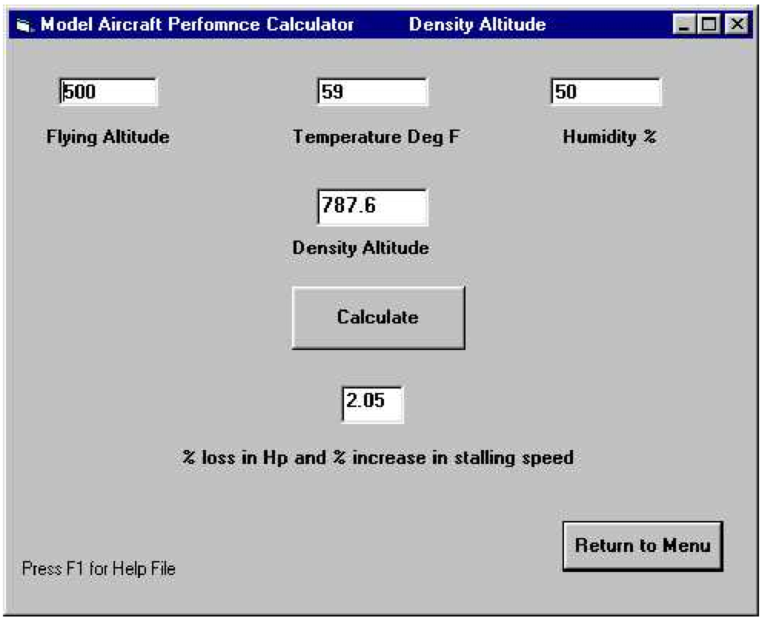
It should be noted that the power and wingloading will simulate the original, The weight is likely to be less as the equipment and radio are fixed proportions of the weight and the ratio decreases with increasing size of the model.

Likewise the structure of our models is not so dense as fullsize.

For example: you wish to increase the size of a model with known flying characteristics:
Increase is to be x 1.5 with the same performance

Size	1	1.5 (Scale)	1.5(APF)
Wing Span	48	72	72
Wing Area	500	1125	1125
Weight	5	16.8	13.7
Wing loading	23	34.4	26
Power	.45	1.86	0.97
APF	75	—	100

Using the Aircraft Performance Factor page will allow a successful design..



Density Altitude

The Density Altitude is the altitude at which the density of the International Standard Atmosphere(ISA) is the same as the density of the air being evaluated.

The basic idea of calculating density altitude is to calculate the actual density, and then find the altitude at which that same air density occurs in the ISA.

The concept of density altitude is commonly used to explain aircraft performance, but the real important quantity is actually air density.

For example the lift, and aerodynamic drag of an airplane, and thrust of a propellor blade are all directly proportional to air density. Similarly the output of a internal combustion engine is related to air density.

Humidity

For a given pressure and temperature moist air is less dense than dry air. Increasing humidity reduces air density and thus the relative altitude density will increase.

This effect is quite small.

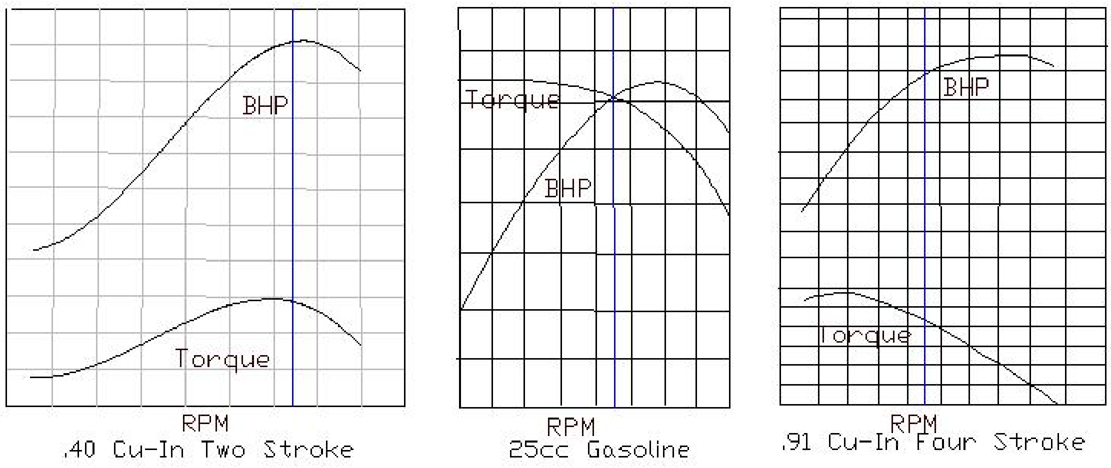
Density Effects

The air density pressure decreases approximately 2.6% per 1000 ft increase in altitude.

Ex: Dallas is at 600 ft, on a hot 100 Deg F day with 50% humidity, the density altitude is 3976.1 Ft. This is a loss of 10.3% in air density.

Power loss is 10%, stalling speed increases by 10%

Typical Brake Horsepower Curves



Torque:

Torque is the force that usually turns things, Ie; rotates the propellor. The combustion of the fuel/air mixture generates the torque to turn the crankshaft and can be measured in Inch Pounds.

Brake Horse Power(BHP):

Brake Horsepower describes the measurement unit of the power available from an engine, that a dynamometer determines by placing a braking load on the crankshaft, and calculating the amount of resistance which the engine can produce.

Dynamometers measure torque, the BHP is calculated from the Torque below;

BHP is a calculation of force(Torque) over time;

$$BHP = \frac{\text{torque(oz-in)} \times \text{RPM}}{1008384}$$

Choosing the propellor for a engine is a compromise that depend upon the model that the engine will power:

-Slow flying models with low wing loading will require lower pitched propellors to match their lower flying speeds.

-Models with higher wing loading have to fly faster to maintain lift and will require higher pitched propellors .

-The diameter (THRUST) of the propellor will depend on how much drag the model will have.

Generally, loading the engine so that it operates at peak torque should produce the most thrust.

For speed, operating at peak BHP will produce the greatest speed potential.

So what to do? For satisfactory performance, load the engine to operate at between the max torque RPM and the max BHP RPM, as indicated by the Blue line on the above graphs.

Trying to generate maximum RPM is not necessarily the best strategy. Select a propellor that performs best with a particular model

.

To choose a propellor for a particular model characteristic, use the Engine/Performance section of this program.

Coefficient of Lift

The efficiency of a wing is greatly affected by its airfoil section or profile.

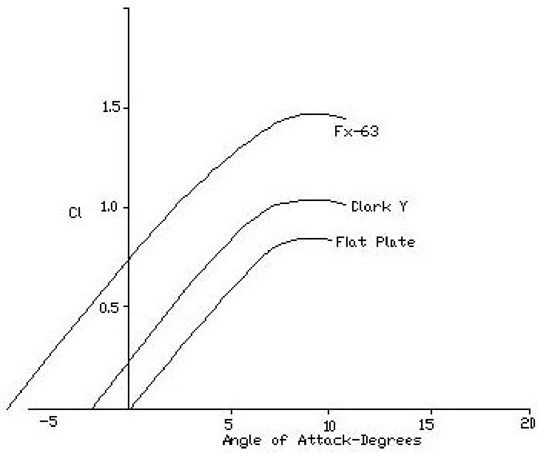
The convention adopted by aerodynamysist is to sum all the complex variables that produce wing lift into one convenient figure, the *Coefficient of Lift.*

*Coefficient of Lift-**Cl,*** tells how the lifting surface is working as a lift producer A lifting coefficient of 1.3 indicates more lifting effect than a lift coefficient of 1.0, a lift coefficient of 0.0 has no lift at all.

$$Cl = \frac{L}{1/2*p*V^2*S} \quad \text{or} \quad Lift = 1/2*p*V^2*Cl$$

So, lift is proportional to the air density p, proportional to the velocity squared and proportional to the Cl.

The value of the Cl also depends on the angle of attck of the airfoil, See Fig below, for three different airfoils.



Pitch

Propeller pitch is the forward travel (in inches) of a propeller during one revolution.

The angle of twist at each blade section is called the angle of pitch.

The twist (for constant pitch) varies along the length of the propeller blade.

Pitch Measurement

Pitch in inches = 2*Pi* R*TangentA

Where R is the distance(radius) out from the hub center to the measuring station.(75%)

A is the angle between the blade and the plane of rotation.

The following chart calculates the angle at 75% for the displayed pitch and diameter

Pitch		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Dia	4	17.7	23	27.9	32.5	36.6	40.3	43.7	46.7	49.4	51.8	54	56	57.8	59.5	61	62.4	63.6	64.8
	5	14.3	18.7	23	27	30.7	34.2	37.4	40.3	43	45.5	47.8	49.9	51.8	53.6	55.3	56.8	58.2	59.5
	6	12	15.8	19.5	23	26.3	29.5	32.5	35.3	37.9	40.3	42.6	44.7	46.7	48.5	50.2	51.8	53.3	54.7
	7	10.3	13.6	16.9	20	23	25.9	28.6	31.2	33.7	36	38.2	40.3	42.3	44.1	45.9	47.5	49	50.5
	8	9	12	14.9	17.7	20.4	23	25.5	27.9	30.3	32.5	34.6	36.6	38.5	40.3	42	43.7	45.2	46.7
	9	8	10.7	13.3	15.8	18.3	20.7	23	25.2	27.4	29.5	31.5	33.4	35.3	37	38.7	40.3	41.8	43.3
	10	7.3	9.6	12	14.3	16.5	18.7	20.9	23	25	27	28.9	30.7	32.5	34.2	35.8	37.4	38.9	40.3
	11	6.6	8.8	10.9	13	15.1	17.1	19.1	21.1	23	24.8	26.6	28.4	30	31.7	33.3	34.8	36.2	37.6
	12	6.1	8	10	12	13.9	15.8	17.7	19.5	21.3	23	24.7	26.3	27.9	29.5	31	32.5	33.9	35.3
	13	5.6	7.4	9.3	11.1	12.9	14.6	16.4	18.1	19.7	21.4	23	24.6	26.1	27.6	29	30.4	31.8	33.1
	14	5.2	6.9	8.6	10.3	12	13.6	15.3	16.9	18.4	20	21.5	23	24.4	25.9	27.3	28.6	29.9	31.2
	15	4.8	6.5	8	9.6	11.2	12.7	14.3	15.8	17.3	18.7	20.2	21.6	23	24.3	25.7	27	28.3	29.5
	16	4.5	6.1	7.6	9	10.5	12	13.4	14.9	16.3	17.7	19	20.4	21.7	23	24.3	25.5	26.7	27.9
	17	4.3	5.7	7.1	8.5	9.9	11.3	12.7	14	15.4	16.7	18	19.3	20.5	21.8	23	24.2	25.4	26.5
	18	4	5.4	6.7	8	9.4	10.7	12	13.3	14.5	15.8	17	18.3	19.5	20.7	21.8	23	24.1	25.2
	19	3.8	5.1	6.4	7.6	8.9	10.1	11.4	12.6	13.8	15	16.2	17.4	18.5	19.7	20.8	21.9	23	24.1
	20	3.6	4.8	6.1	7.3	8.4	9.6	10.8	12	13.1	14.3	15.4	16.5	17.7	18.7	19.8	20.9	22	23
	21	3.5	4.6	5.8	6.9	8	9.2	10.3	11.4	12.5	13.6	14.7	15.8	16.9	17.9	19	20	21	22
	22	3.3	4.4	5.5	6.6	7.7	8.8	9.8	10.9	12	13	14.1	15.1	16.1	17.1	18.2	19.1	20.1	21.1
	23	3.2	4.2	5.3	6.3	7.4	8.4	9.4	10.5	11.5	12.5	13.5	14.5	15.5	16.4	17.4	18.4	19.3	20.2
	24	3	4	5.1	6.1	7.1	8	9	10	11	12	12.9	13.9	14.9	15.8	16.7	17.7	18.6	19.5
	25	2.9	3.9	4.8	5.8	6.8	7.7	8.7	9.6	10.6	11.5	12.4	13.4	14.3	15.2	16.1	17	17.9	18.7
	26	2.8	3.7	4.7	5.6	6.5	7.4	8.4	9.3	10.2	11.1	12	12.9	13.8	14.6	15.5	16.4	17.2	18.1
	27	2.7	3.6	4.5	5.4	6.3	7.2	8	8.9	9.8	10.7	11.5	12.4	13.3	14.1	15	15.8	16.6	17.4
	28	2.6	3.5	4.3	5.2	6.1	6.9	7.8	8.6	9.5	10.3	11.1	12	12.8	13.6	14.4	15.3	16.1	16.9
	29	2.5	3.3	4.2	5	5.8	6.7	7.5	8.3	9.1	10	10.8	11.6	12.4	13.2	14	14.8	15.5	16.3
	30	2.4	3.2	4	4.8	5.7	6.5	7.3	8	8.8	9.6	10.4	11.2	12	12.7	13.5	14.3	15	15.8
	31	2.4	3.1	3.9	4.7	5.5	6.2	7	7.8	8.6	9.3	10.1	10.8	11.6	12.4	13.1	13.8	14.6	15.3
	32	2.3	3	3.8	4.5	5.3	6.1	6.8	7.6	8.3	9	9.8	10.5	11.2	12	12.7	13.4	14.1	14.9
	33	2.2	2.9	3.7	4.4	5.1	5.9	6.6	7.3	8	8.8	9.5	10.2	10.9	11.6	12.3	13	13.7	14.4
	34	2.1	2.9	3.6	4.3	5	5.7	6.4	7.1	7.8	8.5	9.2	9.9	10.6	11.3	12	12.7	13.3	14
	35	2.1	2.8	3.5	4.2	4.8	5.5	6.2	6.9	7.6	8.3	9	9.6	10.3	11	11.6	12.3	13	13.6
	36	2	2.7	3.4	4	4.7	5.4	6.1	6.7	7.4	8	8.7	9.4	10	10.7	11.3	12	12.6	13.3

Control Surface

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Contents

Instructions

To see how this works, lets calculate the stalling speed of a an airplane. The plane has a 50 inch span with a 10 inch average chord, the airfoil is symmetrical. The plane weighs 4 pounds. The altitude of the flying site is 3000 Ft. The air temperature is 80 Degrees F.

First calculate the wing area by multiplying the wingspan by the average wing chord
50" x 10" = 500 Sq. Inches.

Locate the weight section on the outer disk, hold the disk with the weight section uppermost, rotate the inner disk until the wing area in square inches is uppermost, align the wing area of 500 Sq. Inches with the weight, 4 Lb.

Locate the Ounces Sq. Ft window in the inner disk, read the calculated wing loading from where the arrow head is pointing. Ex. 18.5 Ounces Sq. Ft.

The stalling speed is related to the coefficient of lift of the wing. For a symmetrical airfoil the maximum coefficient of lift is approximately 0.8 at a 10 degree angle of attack.

Locate the stalling speed window. Locate the coefficient of lift mark of 0.8, the stalling speed at sea level is aligned with this mark, Ex. 24 MPH.

Rotate the outer disk until the pressure altitude section is uppermost, rotate the inner disk until the density altitude section is uppermost. Align the arrowhead to the left of the density altitude window with the pressure altitude ,Ex. 3(3000Ft).

Locate the temperature band at the top of the density altitude window , by eye, align the 80 temperature to the % stall speed the from the lowest row of numbers, Ex. 117%.

The calculated stalling speed is 1.17 x 24 = 28.1 MPH.

Now lets calculate the approximate HP of an engine.

The engine is rotating a 10 inch diameter, 6 inch pitch Propellor at 12,000 RPM. The altitude of the flying site is 3000 Ft. The air temperature is 80 Degrees F.

Locate the RPM section on the outer disk, hold the disk with the RPM section uppermost, rotate the inner disk until the Propellor diameter in inches is uppermost, align the Propellor diameter of 10 inches with the RPM 12(12000).

Locate the Pitch-Inches window in the inner disk, read the calculated horsepower at sea level from the Propellor pitch of 6 inches. Ex. 0.8 H.P.

Rotate the outer disk until the pressure altitude section is uppermost, rotate the inner disk until the density altitude section is uppermost. Align the arrowhead to the left of the density altitude window with the pressure altitude, Ex. 3(3000Ft).

Locate the temperature band at the top of the density altitude window , by eye, align the 80 temperature to the % engine power from the middle row of numbers, Ex. 86%.

The calculated horsepower is .86 x 0.8 = .69 H.P.
To calculate the approximate engine capacity to generate 0.8 H.P. at this altitude and temperature, divide the engine capacity by 0.86.

Ex. .40 Cu In/0.86=0.46 Cu In

Now calculate the speed and thrust capability of a Propellor at sea level. A 10 inch diameter Propellor with a six inch pitch is rotating at 12,000 RPM.

Locate the RPM section on the outer disk, hold the disk with the RPM section uppermost, rotate the inner disk until the Propellor diameter in inches is uppermost, align the arrow pointing to the airspeed and thrust windows in the inner disk with the RPM 12(12000).
Locate the Airspeed window in the inner disk, locate the Propellor pitch in inches and read the airspeed capability.

Ex 68 MPH.

Locate the thrust window in the inner disk and read the thrust in ounces from the Propellor diameter.

Ex. 58 Ounces=3.6 Lb.

NOTE: THAT ALL THE CALCULATIONS CAN BE REVERSED,
BY STARTING WITH THE REQUIIRED RESULT AND CALCULATING THE NEEDED INPUTS

Technical Section

Horsepower Calculation and Propellor selection
A practical method of determining a Power Coefficient , using test results, is the following;

Pc = H.P./(p x RPM^3 x Diameter^5)

An empirical equation for the power absorbed by a model Propellor, uses pitch to substitute for the theoretical blade loading, and a Propellor factor for model engine usage derived from published test data.

H.P. =(RPM^3 x Diameter^4 x Pitch)/Propellor factor 1.4x10^17

The horse power formula used, is fairly accurate for calculating the horse power generated by an engine, but it is more useful as a method for selecting the appropriate propeller for a given application.

Mathematically this is the measured RPM raised to the third power, multiplied by the propeller diameter in inches raised to the forth power, multiplied by the propeller pitch, all divided by a factor for model propellers. The Propellor factor has been determined by comparing the calculated results against published data on engine horsepower and Propellor sizes.

The RPM and diameter are easy to verify but the actual pitch of a propeller is not so easy. Pitch is traditionally determined by measuring the angle of the back surface of the propeller blade, at 75% of the propeller radius. A pitch measuring gages can be purchased or constructed. Note that marked pitch sizes may not represent the actual Propellor pitch.

If, for example, a engine is rotating a 10" x 6" propeller at 12,000 RPM. The H.P. can be determined from the slide rule by aligning the propeller diameter, 10, on the outer circumference of the inner disc, with the measured RPM on the outer disc, 12. The engine H.P. can be read in the pitch window from the Propellor pitch, 6, located on the inner disc,
Ex =0.8 H.P.

It is important to note that the RPM measured may not be the RPM at which the maximum BHP of the engine is generated or the RPM at which the maximum torque is generated. To maximize the performance of the engine, the RPM at which the maximum BHP and Torque needs to be determined from the manufacturer’s data or published reports in the media.

In the previous example, assume that the maximum BHP is generated at 15000 RPM, and that the max. BHP is +10%, to select an appropriate propeller, chose a pitch, Ex 10", align the pitch value with the H.P. calculated previously plus 10%, 0.9 in the pitch window on the inner disk, (note that this value will approximate the actual maximum H.P. capability, so some adjustments may be required). From the RPM selected ,15000, the propeller diameter can be calculated, 7.7" in this example. Note that if an overly large value of pitch is selected, the calculated propeller diameter can be too small to generate enough thrust for good performance, for the size and weight of the model.

Ex, to maximize thrust, a larger diameter is required, 12". align the Propellor diameter with the desired RPM, 12000, and note that for the available horsepower, .8, a practical pitch is not available, so assume that a 4" pitch is acceptable, align the HP, .8 with the pitch, and the new RPM will be, 10600.
This RPM also could be compatible with the maximum torque RPM.

The same procedure can be used for Propellor selection, for example a four bladed Propellor of the same pitch, 6, and RPM, is required for the above example

Divide the horsepower by two, = .4
Align the new H.P. in the H.P. window with the pitch value, 6. and read the new Propellor diameter, 8.5, from the required RPM.
Home

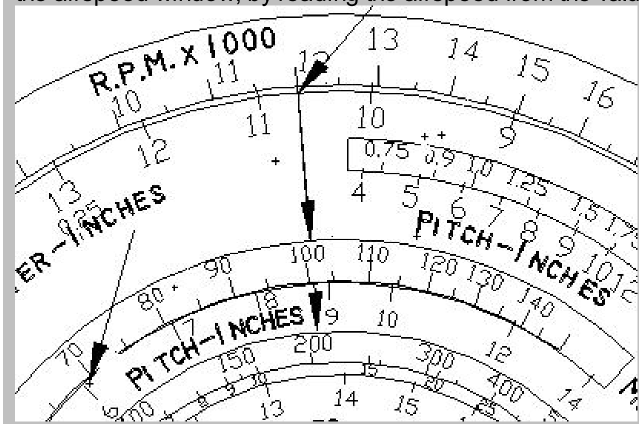
Airspeed Capability

The airspeed capability of the Propellor is determine by the pitch.

Airspeed = RPM x 60 x Pitch/(12 x 5280)

For the above example, 6" pitch, 12000 RPM;

Align the Airspeed and Thrust arrow line with the measured RPM, 12000, the airspeed capability of the Propellor is determined from the airspeed window, by reading the airspeed from the value of the pitch, 6, approximately 68 MPH.



Ex = 68 MPH

This assumes a -10% factor for slip and a +10% airborne RPM increase from the static RPM.

Note that the speed capability of the Propellor may not be achieved in practice if the model is to big and /or heavy for the size of the motor used . Too big and the model drag is too high, too heavy and the drag due to the angle of attack required to generate the required lift, is too high.
Home
Thrust Capability
The theoretical maximum thrust available from a Propellor is defined as;

T = (H.P.)^2/3 x (2pA)^1/3

A is the area of the Propellor.
p = Air density

this is modified by the losses associated with the Propellor and the efficiency, which is a function of the advance ratio J.
The advance ratio is a function of the forward velocity of the Propellor and the RPM.
A fixed Propellor, at a fixed RPM, then has its maximum efficiency at one airspeed, so for model purposes the pitch selection is critical to performance.
Especially for high pitch values, the Propellor can be stalled at low velocities (take off and landing) , e.g. ducted fan jets, racers.

A more practical method, using test results, is to determine the Thrust coefficient using the following.

Ct = Thrust/ RPM^2 x Diameter^4 x Air Density

Thrust =RPM^2 x Diameter^4 x Air Density x Thrust Coefficient(Ct)

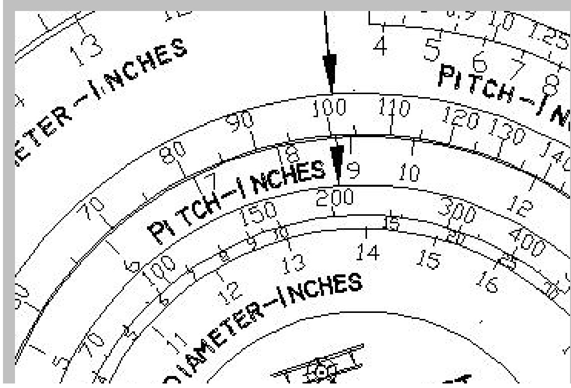
Thrust Coefficient is a combination factor that combines the design of the Propellor, (its shape), the Advance Ratio J, and the Reynolds number of the advancing blade. As these factors are not easily determined for model propellers, a coefficient is determine from measured static thrust figures.

The advance ratio J is of interest , as, as the speed of the aircraft increases the thrust (blade lift) will decrease due to the reducing angle of attack of the advancing blades. This will limit the maximum speed of the model in horizontal flight.

Align the Speed and Thrust arrow with the measured RPM, 12000, and read the approximate thrust

58 Oz (3.6Lb)

from the Propellor diameter ,10.



How much thrust is enough? From practical experience if the static thrust is equal to the model weight the model will have excellent performance.
To be able to hover vertically and for better vertical climbing ability 1.5 to 2 times the model weight is required.

A electric glider using a 05 motor, is a low performance model and would have a thrust to weight ratio of about 0.5. (8 x 3 at 10,000 RPM), and a speed capability of 29 MPH.
Home
Wing loading

The wing loading in Ounces per square foot is calculated by dividing the projected or measured wingspan which would include the area loss due to

dihedral,   by the average chord. The average wing chord is calculated by averaging the root chord and the tip chord.
(Root chord + Tip chord)/2.

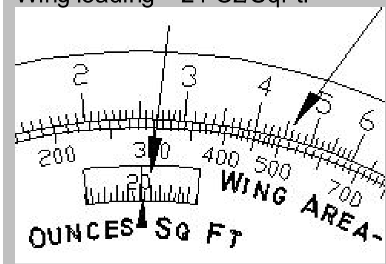
The effect of wing loading varies with size of the model, as the chord increases in width, the effective Reynolds number increases, which will increase the "efficiency" of the airfoils used for model purposes. That is; Larger models can fly with higher relative wing loading.

From the wing loading the stalling speed of the wing can be found.
The stalling speed is a function of the coefficient of lift of the airfoil.
The coefficient of lift is a function of the airfoil shape and its angle of attack.
for example a symmetrical airfoil has its maximum coefficient of lift at an angle of 10 degrees and is approximately equal to 0.8
Home
The stalling speed is calculated from;

Stalling speed =   .68 x ((Wing loading/16)/(.00119 x Cl))^.5

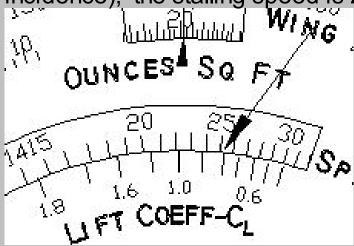
To calculate the speed, align the wing area in Sq. Inches with the weight of the model in pounds.
Read the wing loading in Ounces/Sq. Ft from the wing loading window.

Ex; 500 Sq. In Area, model weight 4.5Lb
Wing loading = 21 Oz/SqFt.



The stalling speed at the calculated loading for a particular coefficient of lift can be read from the stalling speed window.

Ex;   At 21 Oz/Sq. Ft wing loading and a coefficient of lift of 0.8 (symmetrical airfoil at 10 Degrees incidence), the stalling speed is 26 MPH



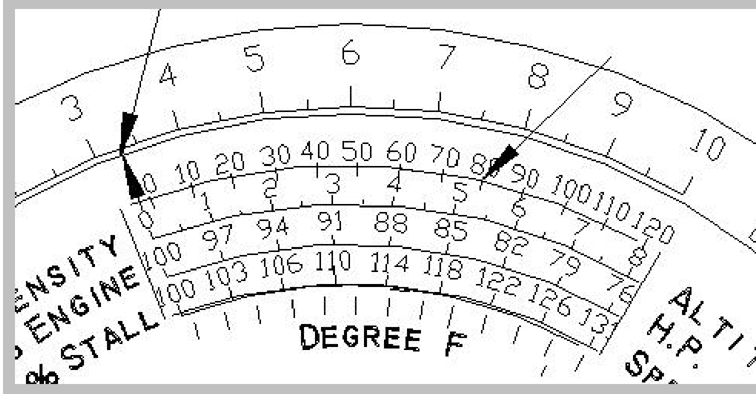
Note that as the coefficient of lift of the airfoil increases, the stalling speed decreases. For example flaps increase the lift coefficient and allow a lower landing speed, flaps also increase drag, so more power is needed.
The stalling speed depend on the density of the air, so at elevated altitudes and /or temperatures the stalling speed will increase. This can be calculated in the Density Altitude window.
Home

Density Altitude

As altitude above sea level increases the air density decreases.
If air density decreases, the performance of the engine decreases and the stalling speed of the wing increases, and for equal lift the model speed must increase.
As the air temperature increases the air density decreases, and causes the same effect as above.
To calculate the density altitude relative to temperature and the local pressure altitude;
Align the temperature arrow on the inner disc with the local pressure altitude in thousands, on the outer disc, and read the density altitude in the window.

Ex   Pressure altitude = 3.3 (3300 Ft), temperature 80 Deg F,
Density altitude = 5.2 (5200 Ft)

Also the approximate engine horsepower is 85% of original, and the increase in stalling speed, 118%, can be read in the window



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Coefficients of Lift

Airfoil	Cl	Angle of attack

FLAT PLATE	0.7	15
SYMETRICALL	0.8	10
CLARK-Y	1.2	10
N60	1.25	10
SD7032A	1.25	12
SELIG 2091	1.35	11
FX-63	1.6	11

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AIRFOILS AT LOW SPEEDS
Selig, Donovan, Fraser Publisher H. A. Stokely

Distributed by:
Design Services
P.O. Box 515382 Dallas, Tx 75251
Telephone: 972-994-0695

Putting it All together

Requirement: 1/3 Scale Cub that will fly realistically

A 1/3 scale cub will have a wing area of 0.1089 of the original 180 Sq Ft = 2822 Sq In (Scale Factor)

Click on the Gas option Aircraft Performance Factor

Input the area in the APF yellow box, and click on the graph above the sedate area at a PF of 100 (APF)
The results are:

- **Weight 22 Lb**
- **Engine 1.35 Cu-In Gas (1.2 HP per Cu-in= 1.62 HP)**
- **Wing Loading of 18 OZ- Sq/ Ft**

At a wingloading of 18 Oz-Sq/Ft, the stalling speed will be 19 mph with a Cl of 1.2(Clark Y) Wingloading

Estimating the RPM of the engine to be 7500 RPM,. then from the Engine performance graph

At a pitch of 6 in, the required propellor is 17.3 in Dia

This gives a airspeed potential of 43 mph with a thrust of 13 Lb

The scale airspeed is 47 MPH(Scale Factor) so using the red line, a suitable propellor would be a 17 x 6.5, which has a thrust of 12 Lb

A realistic flying plane.

Technial Support