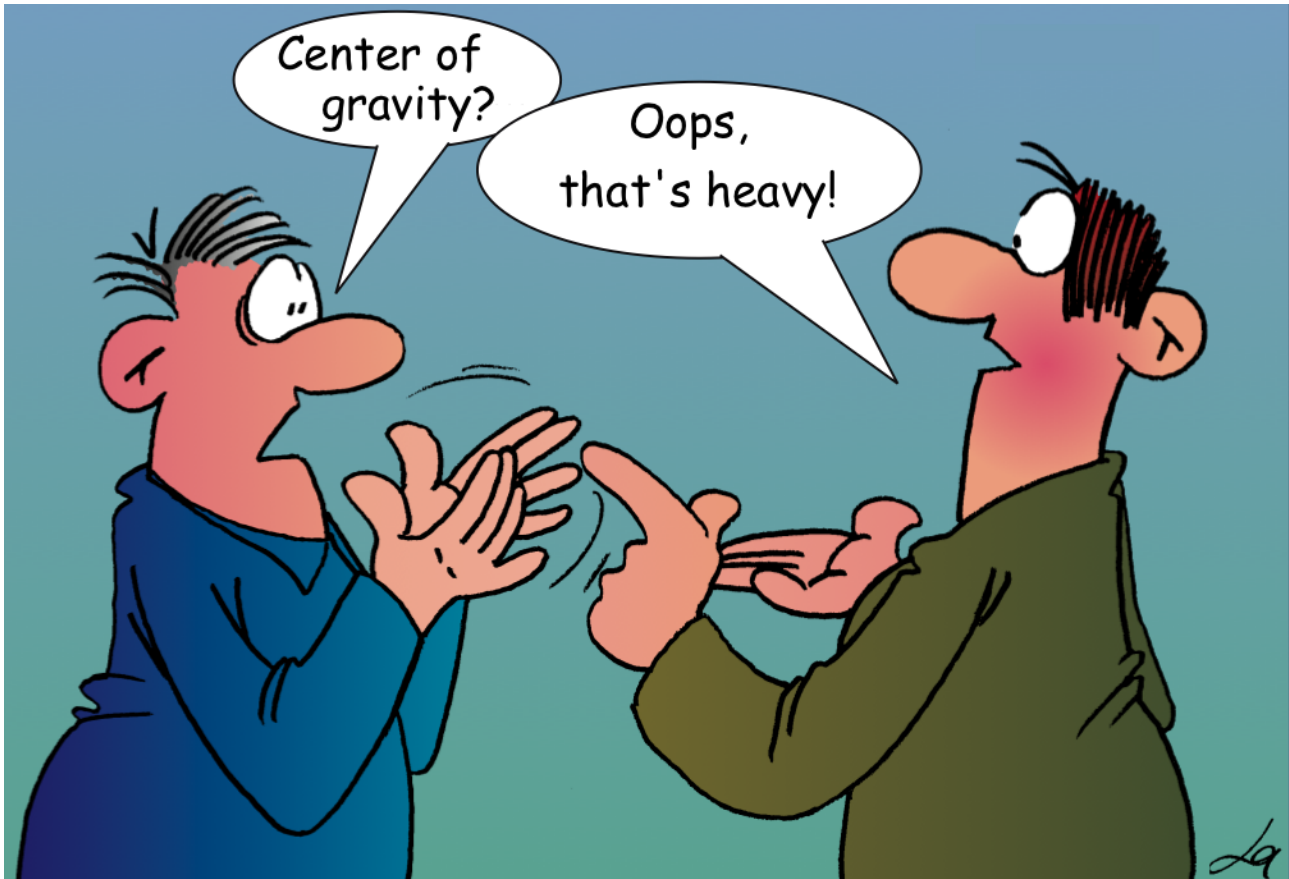


# Manual for the PC Program *WinLaengs4*

By Joerg Russow and Dietrich Meissner



## Introduction

An aircraft is expected to have a flight behavior that makes it as easy as possible for the pilot to control it. The aircraft should be inherently stable and the control surfaces effective so that the desired maneuvers are easy to fly. If this is the case, one speaks of good flight characteristics. This applies in particular to the longitudinal motion, which pilots control with the elevator. Important parameters are airspeed, angle of attack and pitch attitude.

An essential prerequisite for good flight characteristics in the longitudinal motion is longitudinal stability and here first of all static longitudinal stability. To ensure static longitudinal stability, the center of gravity (CG) of the aircraft or model aircraft must be within a reasonable and favorable range. The CG position also modifies the dynamic longitudinal stability.

In the following, the computer program *WinLaengs4*<sup>1</sup> is presented, which first calculates the position of the total aircraft neutral point NP, also called aerodynamic center AC. In the second step, empirical values for the required longitudinal stability are taken into account and a favorable CG range is proposed.

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<sup>1</sup> *Laengs* means *longitudinal* in German.

The user has to first measure the geometry of his model correctly. Depending on the geometry that requires tools like measuring tapes, rulers and squares. The measuring is admittedly a little fiddly, but it cannot be avoided. Sometimes the construction plan can help.

The measured values are then entered into the program and saved as a named data set. The computer does the scientific-mathematical calculations after pressing a button. The result is the position of the AC and a suggestion for the favorable CG range relative to a user-selected reference point.

It works for powered and glider models and can cope with delta, canard and multiplane configurations. Fuselages and (a pair of) floats can be considered as one of the "wings" as long as they have a simple geometry. A total of 5 wings can be entered. Each wing may have multiple trapezium outlines.

### Installation and basic use of *WinLaengs4*

When unpacking the downloaded zip-file a folder "W\_Laengs4\_Vxxx" is created. It contains an executable (W\_Laengs4\_Vxxx.exe) and some already created data sets of models in the subfolder "Beispiele" (=Examples), which can be used as a template for own designs. The folder can be copied to any location on any drive. An installation routine for the program is not required.

If you start the program, you will see a picture with the general view of the current aircraft, Figure 1.

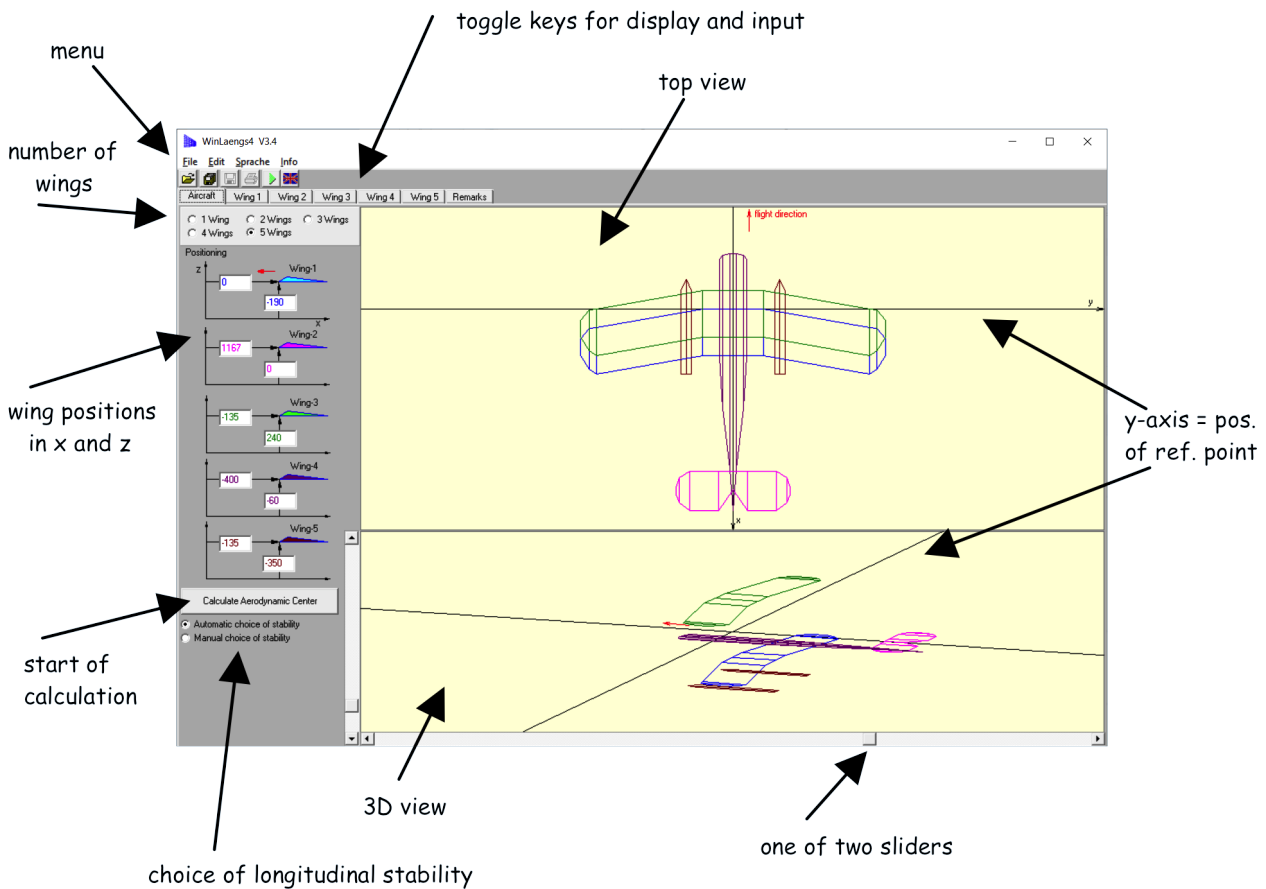


Figure 1: After program start

A picture of a biplane with floats is shown as long as no other data set is loaded. Figure 1 shows the representation before a calculation is started. This configuration has the maximum number of 5 wings. In this case the fifth wing consists of the pair of floats.

Now you can use the usual elements of a graphical user interface (menu items and buttons) to either load another data set or edit the existing data set. The path to a loaded or saved data set is displayed at the top.

For editing, the correct number of wings should first be selected with the radio buttons. Each wing is assumed to be symmetrical to the x-z-plane. Then enter the x and z values of the leading edge of the center cut of the wings as positions or offset values. The coordinate system lies in such a way that x counts backwards and z counts upwards positively. Y values do not occur at this point but the intersection of the x and y axes points out the position of the user-chosen reference point. The center of gravity position will be proposed relative to this point.

Afterwards each of these wings can be edited by selecting the corresponding tab "Wing 1" up to a maximum of "Wing 5" at the top left. The following input mask for the wing geometry is shown in Figure 2. What has to be entered here should be self-explanatory. Put the values in the corresponding fields, representing the wing within its own wing coordinate system x and y. (The position of each wing coordinate system relative to the aircraft coordinate system in x and z are the offset values mentioned before.)

Moreover, in the graphical representation of the geometry, you can move certain points with the mouse. In this case, the corresponding input fields are highlighted in yellow and updated when the mouse is released. The processing always refers to the right wing half, the left wing half is always symmetrical to it. The input data can be checked by the top view.

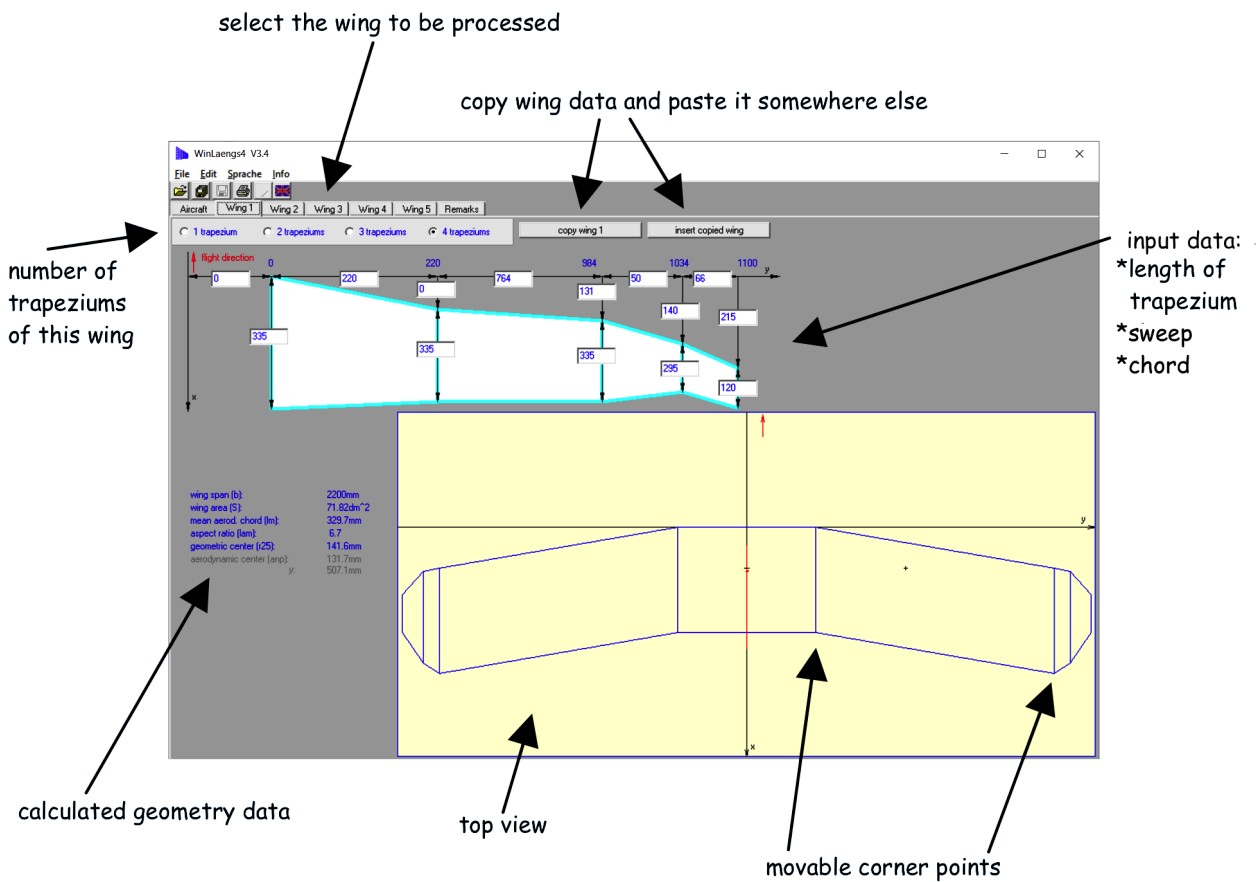


Figure 2: Edit wing data

After all wing data have been filled in, we can return using the tab "Aircraft". Two views (top view and variable 3D view) can be used to check whether everything is correct. The 3-D representation of the aircraft can be rotated by the sliders and zoomed with the mouse when the mouse pointer is in the 3-D window. The left mouse button is used for rotating in 2 axes and the right mouse button is used for zooming and rotating in one axis.

Now the calculation of the AC can be started by means of the green arrow in the menu (Figure 3) or the corresponding button "Calculation ..." at the bottom left. Depending on the complexity of the configuration, millions of arithmetic operations are performed, which can take a few seconds. The calculated position of the AC relative to the reference point is displayed in the top view window as x-AC and entered in the image as a red line. In our example the calculated AC is 116.5 mm behind the reference point.

In addition, two blue lines representing the front and rear ends respectively mark the automatically suggested CG range. This range is given as a percentage of the reference length  $l_{\mu}$  (or  $l_m$  in the program window). The CG should be in the range 64 mm to 90 mm behind the reference point.<sup>2</sup>

The assignment of the numerical results to the graphical markers is displayed with a mouse click into the aircraft top view.

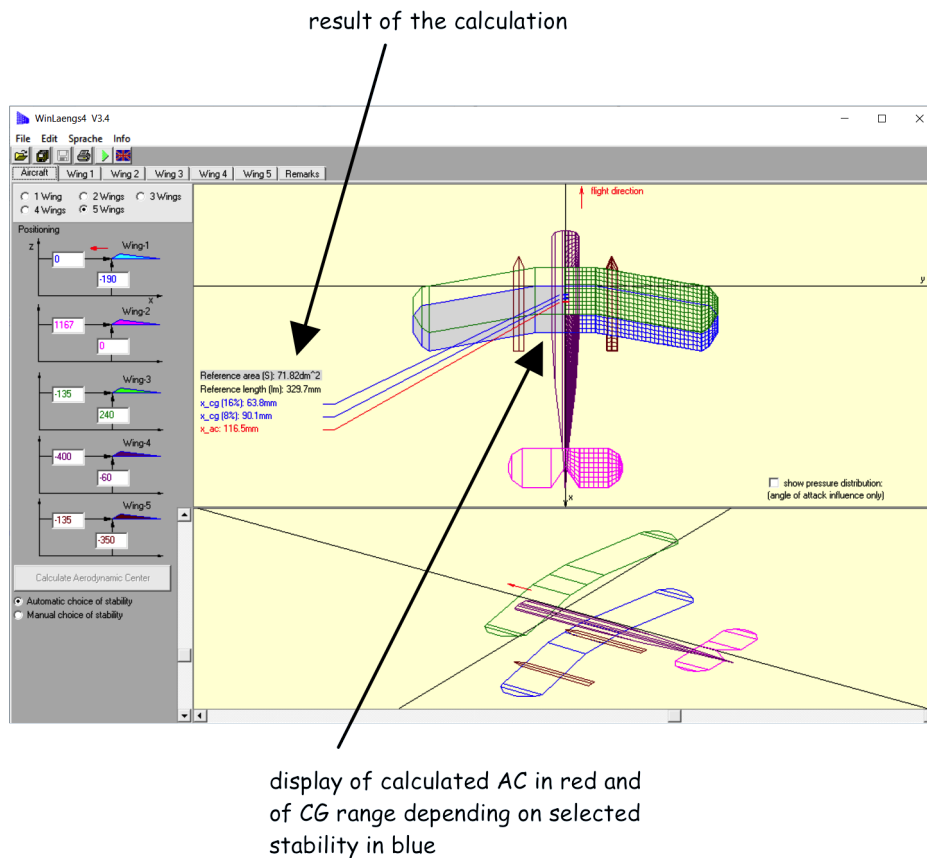


Figure 3: After calculation

<sup>2</sup> In this case the reference length  $l_{\mu}$  is 329.7 mm. 8 % of  $l_{\mu}$  is 26.4 mm. By this measure the CG should be in front of the AC. This results in the following for the position of the CG: 116.5 mm - 26.4 mm = 90.1 mm, to be understood as a measure behind the reference point. Accordingly, the front edge of the CG Range is 63.8 mm behind the reference point at 16 %  $l_{\mu}$  static longitudinal stability.

Afterwards, if desired, you can set your own value with the radio button "Manual selection of stability" using the slider. The value can also be entered directly into the input field with the keyboard. In this case only one blue line is shown in the image, which shifts accordingly.

The result is saved with the data set. The result can be printed, too.

### Some computer related hints for working with *WinLaengs4*

- The user interface can be displayed in German, English and Spanish. This can be selected in the pull-down menu "Sprache" or "Language" or with the button with the flag. The program remembers the selected language in a file "Default.pa4", which is located in the same directory as the *WinLaengs4* program. If the Default.pa4 file does not yet exist, it will be created. The next time the program is started, the last language setting used should be set automatically. Attention: There are problems with remembering the last language setting if the write protection of the Default.pa4 file is activated, which can happen e.g. if the file has been copied to CD and back to a normal drive. If this problem occurs, please delete the "Default.pa4 file" or remove the write protection of this file.
- When entering the wing and aircraft geometry, only integer values should be entered. A decimal point may be used when entering a manual value for longitudinal stability. If necessary, please use the "." sign (dot) as decimal sign. However, actually integer values in % are accurate enough here, too.
- The program can calculate almost any wing geometry, but not really any. The program tries to divide the individual trapezium of the wings into even smaller trapeziums (panels), which are then favorably distributed over the wing for the calculation. (They become visible on the right half of the surface after the calculation is started). If one depth of the entered trapezium is very small in relation to its opposite depth or even zero (the trapezium is actually a triangle), the program may not be able to cope with it. In this case, a corresponding error message is displayed when attempting the calculation, e.g. "Error: Cannot calculate wing 1 / trapezium 3. Please change this trapezium (outer depth greater)!". The only remedy is to enter a slightly larger value for the wing depth of the trapezium in question. This does not significantly reduce the accuracy.
- The numbering of the wings has no influence on the result, you can swap them in the menu. If you want to hide one of the wings for the calculation, sort it as the last one and reduce the number of wings by 1. The hidden wing will still be saved.
- You can copy individual wings and add them to another or the same data set. See the corresponding buttons.
- A rear wing (typically the horizontal tail) must have a different z-position than the wing(s) in front of it, for programming and mathematical reasons. However, the z-position is not critical, which can easily be verified by control calculations with different z-values. The position of the calculated AC will only shift by a minimal amount depending on the z-position of the horizontal tail.
- If a gap is left in the middle of a wing to place the fuselage there, the warning is given as a precaution: "**Are you sure that this wing should have a gap in the middle?**". This is to remind you that this gap must be closed with the help of another wing (usually the wing that represents the fuselage). After the calculation, the (half) reference plane is displayed with a grey background on the left side of the aircraft in the plan view. This is for information purposes only.
- The automatic selection of the longitudinal stability works as follows: If only one wing is selected (typical for a delta or flying wing), it recommends a longitudinal stability range of 4 to 8 % of the reference length  $l_{\mu}$ . If there is more than one wing, the recommendation is 8 to 16 %  $l_{\mu}$ . Not quite perfect is the case of a tailless one with a fuselage modeled as a second wing. Here the user should rather take the values of the flying wing and select the stability (e.g. 5 %  $l_{\mu}$ ) manually.

- When printing, the program tries to fit the printout onto one page. For this purpose, the printout is automatically zoomed according to the printer and operating system used and should always be the same size. Selecting the printer resolution influences the quality of the printout. Here, the larger the "dpi number" the better the print. The offered printer resolutions depend on the printer used. For color printers, black and white printing can be set in addition to color printing.

### **How to work efficiently with *WinLaengs4***

The calculation of the aerodynamic center (AC) requires the input of the relevant geometrical data of the aircraft or model. This is the number, appearance and position of a maximum of 5 wings in the top view as well as their position in the side view. If you already find a similar-looking design in the examples, you can load it and save it under a new name with correspondingly adapted dimensions. This saves work. The work of measuring the model correctly has to be done very carefully and takes its time. The top view and 3D image make it easier to check the geometry data.

First of all, one should determine where the reference point (RP) of the model should be, from which the positions of the individual wings are measured and to which the positions of AC and CG later refer. The position of the selected RP is marked in the overview screen of by the point of intersection of x- and y-axis.

In a conventional model with wing in front and horizontal tail in the back, you will almost always choose the leading edge of the main wing at the fuselage as RP. The AC is then located behind this point (some mm behind the leading edge), which gives a positive x-value. If the wing is extremely forward swept or on a canard aircraft (horizontal stabilizer in front of the wing) the value for the AC position relative to the RP can be negative.

For models with a heavily swept back leading edge of the wing, such as a delta wing, it may be more practical to define the trailing edge of the wing as the location of the RP. For this purpose, the root depth of the wing is entered as negative x-value as wing position (x offset). In this case the calculated x-values for AC are negative, because they are in front of the RP. However, it can also be useful to select the tip of the fuselage as a reference point. The position of all points is shown in the drawing after the calculation, which allows a simple check for plausibility.

If the fuselage is relatively wide and protrudes far forward, it should be included in the calculation, as it shifts the total AC forward. A fuselage is not represented three-dimensionally, but is described by a surface that corresponds to the bird's view. It is also numbered as one of the wings. (The fuselage height does not play a major role for longitudinal stability and is neglected, as is the profile thickness of a wing).

You can leave a gap in the middle of the main wing for a fuselage at the same z-position. It is important that the wing gap corresponds exactly to the width of the fuselage, so that no gap or overlap remains (in y-direction). The program itself can handle gaps between the wings. But, the result does not fit our model, if in reality there are no gaps. And airplanes with gaps between wings and fuselage are extremely rare!!! Attention, mistakes are often made here!

All wings (thus also the actual fuselage) consist of up to 4 trapeziums (at each wing half). The trapeziums are flush with each other and the outer depth of the trapezium n is equal to the inner depth of the trapezium n+1. To represent a depth jump between 2 trapeziums, a trapezium with a y-extension of 0 mm is inserted between them as n+1 and the wing is continued with n+2. The jump then results between the end of trapezium n and the beginning of trapezium n+2.

If you want to enter more than 4 trapeziums for a certain wing, you can do this by representing this wing by several individual wings, which must then be at the same z-level. This can be easily achieved with the help of the gap function, whereby the individual wing parts must fit together seamlessly. The calculated AC remains correct. However, in this case the reference length  $l_{\mu}$  will not refer to all parts of the wing! The wing (or here: part of the wing) used for

calculation of the reference length (and reference area) is the grey-shaded area on the left side of the aircraft.

How to calculate a wing with dihedral or a V-tail? Enter the projection of these wings from a bird's eye view and the mean height as z-value.

## First Flight

During the first flight the most important thing is to adjust the elevator trim angle, to check the elevator's deflection range and to check if the selected CG position suits your personal needs. These quantities are not independent of each other. If you have checked CG by calculation beforehand, you are already in the green zone at least as far as longitudinal stability is concerned and you run less risk of experiencing a surprise on the first flight. Therefore, the more precisely the favorable CG range is known the better.

### Step 1: Trimming (=Balancing)

After the start of the model (e.g. throwing a glider on a slope) each pilot will first trim a glider to a reasonable slow airspeed by using the elevator trim. In powered flight the trim will be more like a fast horizontal flight at full throttle. Anyway, the elevator trim lever on the transmitter is used for this, the effect of which will hopefully be sufficient. If not, land immediately and adjust the elevator linkage accordingly. If the elevator linkage has yielding and/or play, you can actually pack up and go home. Without proper trimming all further steps are useless.

A more forward CG position requires a tail incidence angle (TI) generating a more nose-up pitching moment than a rear CG position in order to trim the same airspeed. It is irrelevant whether the pitching moment is generated by turning the complete horizontal tail (TI) or by using the elevator. It is only unsightly if the elevator is not set to zero when the aircraft is trimmed. With an all-moving tailplane there are no such problems. Apart from that, however, the size of the TI hardly indicates anything relevant.

### Step 2: Optimize CG position

By setting the model CG according to the calculation results, a flyable CG position and thus longitudinal stability is guaranteed. Now it's time for fine-tuning. If a CG position in the forward part of the recommended range has been selected, it may be useful to choose a (subjectively) better position by successively shifting the CG backwards.

The usual procedure to test this is to tilt the well-trimmed glider's trajectory downwards by pressing the elevator stick lightly for a few seconds. Once the flyer has caught up some speed, the stick is released again. With a favorable CG position you can then observe a relatively slow recovery from the nosedive, which usually changes into the so-called "phugoid", a low-frequency oscillatory aircraft motion with varying airspeed, altitude and pitch attitude, if no intervention with the elevator is made, see /2/. A "slow recovery" is of course not a clear statement and has to be understood relatively. A greater static longitudinal stability leads to a faster recovery and less damping of the subsequent phugoid. On the other hand, so-called "undercutting" is observed in models that are poorly stable or even unstable, but also when wings have little torsional stiffness or fuselages are flexible: once the glider has taken a clearly negative trajectory angle, there is then a tendency to reinforce that nosedive rather than recover. Then only a quick intervention with the elevator will help.

What you want is a clear but not excessive tendency to recover from a dive. This results from a medium center of gravity position, as suggested by the calculation program. If a clear recovery is still visible, the CG can be moved further back about 10 mm (for a medium-sized model) as a test and then start again at step 1. However, it should again be expressly pointed out that there is no CG position that is objectively optimal from a flight quality point of view. Here the personal "taste" varies from pilot to pilot.

### Step 3: Adjust elevator deflection

The required elevator deflection in push and pull direction depends on the selected CG position. (More deflection than necessary should not be provided for.) The final determination can

therefore only be made last. With low static longitudinal stability (i.e. a CG position just in front of the AC), a smaller deflection is generally required, e.g. for looping or stalling the aircraft. This will not be discussed in detail here.

In case of doubt, ask an experienced pilot to check the size of the deflections (also of aileron and rudder, which however do not significantly depend on the CG position). This also applies to the exponential values of the sticks.

In the case of a powered or acrobatic model, the criteria for CG position and elevator deflection may be slightly different. Without wanting to completely roll it out, here are just the keywords: spinning, knife flight and vertical climb. In addition, it is still necessary to check the engine incidence. The more longitudinal stability, the more (negative) engine incidence is needed.

And now we wish you much success in using *WinLaengs4*!

### **Disclaimer**

The program and the content of this manual have been compiled with meticulous care and to the best of our knowledge. However, we cannot assume any liability for the completeness or accuracy of the manual. Furthermore we have no influence on whether the program is used correctly by the user.

### **Literature**

- /1/ [https://en.wikipedia.org/wiki/Longitudinal\\_static\\_stability](https://en.wikipedia.org/wiki/Longitudinal_static_stability) and a lot of other websites refer to this topic.
- /2/ <https://en.wikipedia.org/wiki/Phugoid> and other websites about Longitudinal Dynamics

You might also want to google for the term "vortex lattice method" in order to get an idea how *WinLaengs4* works.

## **End of Manual for the program *WinLaengs4***