

# UliSpeed

Vers. 2.1

User's Manual

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UliSpeed.exe was compiled with the Intel<sup>®</sup> Fortran compiler for Windows. When you start it for the first time, some OS can block the execution and display a message that UliSpeed might contain a risk to your computer. The reason for this message is the fact, that UliSpeed comes without a certificate and Microsoft tries to enforce its own certification process. Since UliSpeed is free software, it is impossible to buy every year an expensive new certificate. You can click on the information button in the message, “accept the risk” and run the program.

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## 1 INTRODUCTION

The aim of my work is the extended use of the computer in the design spiral. The computer is an ideal tool when it comes to multiple iteration loops as in the optimization process for the design of a sailing yacht. In the past, I published the program UliTank to calculate the hydrodynamic forces on a sailing yachts hull and the program UliSail for the calculation of the sail forces. The logical next step is the combination of both programs to create a velocity prediction program (VPP) that determines the equilibrium of forces and moments. The detailed description of the theoretical background is contained in reference [1]. There are significant differences between the new VPP and classical VPPs, like e.g. the one published by the ORC [2], see [1] for the details. It is no surprise that the additional computations significantly increase the runtime on the computer, but the benefits are more detailed and accurate results and an insight into the flow-field. Such an insight is usually only available from CFD-methods that have longer runtimes, without the possibility to directly optimize the trim-parameters.

The update 2.1 contains several new features and some bugs that occur with extreme parameter combinations are eliminated. The definition of the rudder is now easier.

## 2 INSTALLATION OF THE PROGRAM

The zipped file that you downloaded contains the executable file UliSpeed\_2.1.exe, this manual, four sub-directories and the excel-file D33.xlsx. You should extract these files into a new folder of your choice (e.g. UliSpeed). Nothing else will be installed on your computer. You can run the program within this folder. It requires a Windows operating system for 64-bit architecture. The subdirectories should not be renamed or deleted. The additional file D33.xlsx contains two sheets with diagrams. It shows you, how the output files can be used, to illustrate the results. If you want to uninstall the program, you just need to delete the complete folder UliSpeed. On today's machines with several cores, it is possible to run several copies of UliSpeed in parallel. This will speed up the task, when a polar diagram for different courses is desired. You can copy the complete folder in this case and rename the program UliSpeed2.exe etc.

### 3 THE INPUT FILES

The offsets of the hull are stored in the folder OFFSETS. The name of the file must be OFFS\_###.txt. The additional hull-, sail- and control- parameters are stored in the folder INPUT. The name of this file must be USP\_###\_in.txt. The ### stands for three digits or three characters that the user can choose to distinguish between different projects. The three digits or characters will also be used in the names of the output files. The folder APPEND contains the file that describes the keel and rudder of the yacht. The name of this file is specified in USP\_###\_in.txt and must be in the form #####.txt, containing eight characters. The structure of the input files can best be understood by examining the examples OFFS\_D33.txt, USP\_D33\_in.txt and AP\_DEL33 that are contained in the downloaded folders. These three files describe the yacht Dehler 33 of 1996.

#### 3.1 The offset-file

It is mandatory to describe the hull surface in the form of offsets. Other descriptions of the surface (e.g. an IGES-file) are not supported. The hull offsets are the x,y,z-coordinates of the surface points along the sections from keel to deck level. Each section can have different z-values. The x-axis lies in the symmetry-plane in the fore and aft direction. The y-axis has its origin in the symmetry-plane and runs at right angles to it. The z-axis is parallel to the mast. The positive directions of the x- and z-axis must be specified in USP\_###\_in.txt. The origins of the x- and z-axis are automatically determined by the program. When the sections are fixed in the CAD-model, the transom and some stations forward of the designed waterline should be included, since the size of the transom- and bow- overhang has an influence on the resistance. There are three different formats that can be read by the program. The chosen format must be declared in USP\_###\_in.txt.

The simplest format (FORMAT = 1) is just a list of points. Each point starts at a new line and the x-, y- and z-coordinate are separated by a blank, a comma or a tab stop. Make sure that a decimal point is used inside the numbers and no comma. All points that belong to the same section have the same x-coordinate and must be listed consecutively. A change in the x-value will indicate the beginning of a new section. This format is used in the file OFFS\_D33.txt and it can be regarded as an example. It was created from an IGES-file using Rhino. The format with the code FORMAT = 2 is used when the offsets are written by the program DELFTship. An example of this format is OFFS\_DSH.txt.

The third possibility to import offsets is FORMAT = 3, which specifies the GHS-format. Many CAD-programs offer this export format. UliSpeed starts reading the file at the line with the asterisk. All the lines above are ignored and can be used for comments. Some programs like DELFTship add additional points at deck-level. In this case, the usage of GHS is not possible because UliSpeed can only identify points on the hull-surface or on the symmetry-plane. If there is no other possibility to export the sections, then the deck-points must be deleted manually.

#### 3.2 Hints to create an offset file

The easiest way to create an offset file is to run UliLines-3.3 or UliLines-4.4 with the parameter CADOUT = 4. One only has to move the output file from UliLines to the folder OFFSETS.

If you have created the hull in Rhino, you should define between 30 and 50 vertical planes. You might want to use a closer spacing at bow and stern. Create the intersections between these planes and the hull surface. Define points on these intersection-curves: go to Curve – Point object – Divide curve by – Number of segments, type "40" and use the option "mark ends = yes". Make sure that there are no other, previously created points on this layer, switch all other layers off and use the command: Save as – Points (\*.txt), separated by blanks. Transfer this file into the folder OFFSETS and rename it OFFS\_###.txt.

A hull that was created in ProSurf can be exported using the option Data File Output – GHS Output. Prior to that you have to define between 30 and 50 stations using the command: PlaneCuts – Initialize Lines. Many CAD-programs convert the units into feet and change the positive x-direction when the export option GHS is chosen. ProSurf does not do that; the coordinates are exported as drawn. In case the offsets are measured in feet, a value of 0.3048 should be entered for SCALE (see below).

If you use DELFTship to design a hull, you should define 30 to 50 stations using the command: Intersections – Stations. Select the medium precision and write a .txt file via Project – Save as – Stations. Transfer the file into OFFSETS and rename it into OFFS\_###.txt. The file OFFS\_DSH.txt is an example.

### 3.3 The file USP\_###\_in.txt

The purpose of this file is the collection of the control parameters, the geometric parameters of the rig and the input of the environmental conditions. The input file is built by a sequence of line-pairs. The first line always contains an explanation and the second line the numerical value of the parameter. The program reads only every second line and in that line only the first number until the first blank behind this number. The rest of the line is ignored. This is convenient if you want to test different values for a parameter and you want to memorize what has been tested: just move it to the right and type the new value in the left-most position. The input parameters are not all checked for plausibility. You can easily crash the program when you specify silly values!

As an example, we will run the program for a Dehler 33. Let us inspect the file USP\_D33\_in.txt line by line:

```
Headline:
*   Dehler 33   *
AIRTMP = air temperature in Deg. Celsius
    15.0
VTW10  = true wind speed at 10 meters height in (kts)
    10.
BETATW = true wind angle relative to x-axis in degr.
    41.
WATER   1 = fresh water, 2 = seawater with 3.5% salinity
    1
WATTEMP = water temperature in Deg. Celsius
    15.
CLIMAT = wave climate: 0= no waves, 1= wind driven, 2= individually specified
    1
PARAM1 = 1st parameter wave spectrum: fetch (nm) or wave height (m)
    10.    0.15
PARAM2 = 2nd parameter wave spectrum: duration (h) or peak period (s)
    2.     7.7
```

In the second line, the user can type a description of the yacht or of the project. This headline will also appear in the output files.

AIRTMP specifies the ambient air temperature and VTW10 is the true wind speed at a height of 10 meters in knots. BETATW is the true wind angle (bearing) with the boat at rest, relative to the centerline (x-axis) of the boat. WATER indicates whether you sail in fresh or in sea water and WATTEMP specifies the water temperature.

The following three parameters are needed to calculate the added resistance in waves. CLIMAT specifies the wave climate. With Climat = 0 you switch off the waves. The value 1 indicates a JONESWAP-spectrum [3]. If you type 2, you can specify wave height and peak period separately. PARAM1 is the first parameter. For Climat = 1 you should prescribe the fetch in nautical miles in this place, for Climat = 2 it is the significant wave height in meters. With PARAM2 you specify the duration of the wind in hours if Climat = 1, or the peak period in seconds, if Climat = 2.

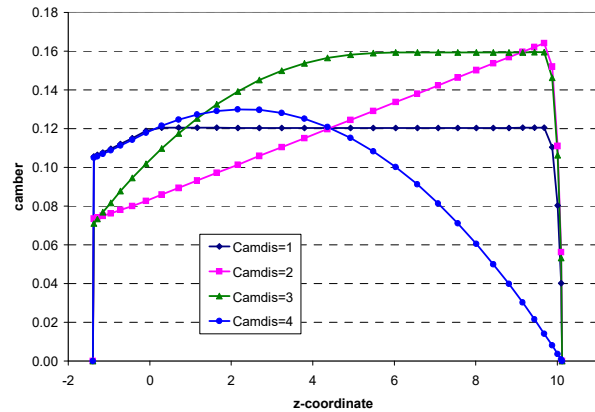
The following parameters define the geometry of the headsail. The DWL is the designed waterline. The z-axis is upward along the mast, starting at the gooseneck.

```
LMAST = length of mast above deck level in (m)
    14.46
SAILI  = vertical height from deck level to mast fitting of forestay = "I" in (m)
    12.
JHOIST = length of jib-luff in percent of length of forestay
    96.
SAILJ  = horizontal distance on deck from forestay to front of mast = "J" in (m)
    3.42
LPMAX  = maximum of "luff perpendicular" measured at right angle from forestay to clew in % of "J"
    142.
HTACK  = height of the lower end of the forestay above the DWL in (m), assumed to be general deck level
    1.18
HCLEW  = height of clew of foresail above deck in (m)
    0.7
PROFIL = profile of headsail: NACA-mean = 1, parabola = 2
    1
SHEETA = sheeting angle of foresail at deck level in degr. At foot rail = 100.
    11.    100.
CAMDIS = distribution of camber for the Jib. 1=constant, 2=linear, 3=parabolic, 4=decreasing
    3
RTWISTJ = reduction of twistcurve in the middle of the jib in degr., -5.< RTWIST <5., linear=0.
    0.
```

The parameter HTACK requires an explanation. The program uses a simplified model of the hull. Cabin and cockpit are ignored and a flush horizontal deck, parallel to the DWL, at a distance of HTACK above the DWL is assumed. This significantly reduces the complexity, without deteriorating the results for an engineering accuracy. The sections in the offset-file are extrapolated in the vertical to the level of HTACK to form this virtual deck.

With PROFIL the profile of the headsail can be specified. Profile no. 1 uses a NACA-mean line, whereas profile no. 2 exhibits the contour of a parabola. When sailing close-hauled up-wind profile 1 will give higher driving forces, but for true wind angles >70° the parabola will give better results. The maximum camber for profile 1 is 18% and for profile 2 it is 36%. SHEETA fixes the sheeting point of the headsail. The sheeting angle is measured on deck from the centerline to a line from the chainplate of the forestay to the car on the genoa track. The clearance of the sail to the shrouds and spreaders must be observed. On reaching courses it is better to lead the sheet to the foot-rail. Insert 100. in this case.

The parameter CAMDIS defines the distribution of the camber on the headsail. The number 1 stands for a constant camber on the entire sail. If number 2 is specified, the camber will increase linearly from foot to top, with number 3, the camber will follow a parabolic curve and with number 4 the camber will decrease towards the head. Sailmakers prefer curve 3. In heavy winds curve 4 is helpful to decrease heel.



RTWISTJ modifies the sheeting angle of the jib. If it is set to zero, the angle will increase linearly from foot to top. Measurements of the flying shape on the sailing dynamometer Fujin showed that the top of the sail could twist more under the wind pressure, than the middle of the sail. In this case, the middle of the sail might have a camber that is 3° reduced compared to the linear distribution. In such a case, RTWISTJ can be set to 3.

The following parameters define the geometry of the spreaders and the position of the shroud. If LSPRED is not zero, the program will check, if the spreader intrudes into the headsail. If this happens, it is necessary to increase X3, or X4, or SHEETA, to increase the distance of the sail to the spreader.

```
LSPRED = length of the upper spreader in (m), if no check required = 0.
0.69
ANGSPR = sweep-back angle of the upper spreader in deg.
20.
ZSPRED = height of the upper spreader above the boom in (m)
6.94
LSPRDL = length of the lower spreader in (m)
0.9
ZSPRDL = height of the lower spreader above the boom in (m)
3.04
DCHNPL = distance of shroud-chainplate from centerline in (m), if no check required = 0.
0.91
```

The following parameters describe the mainsail. The mast diameter will be calculated from:

$$D_{mast} = D_{mast1} \cdot \sqrt[3]{1 - \left(1 - \left(\frac{D_{mast2}}{D_{mast1}}\right)^3\right) \cdot \frac{z}{P}}$$

z = vertical distance from gooseneck

```
SAILP = vertical length of the luff of the unreefed mainsail along the mast = "P" in (m)
12.8
REEFP = vertical height of head of mainsail above the boom in % of "P"
100.
SAILE = horizontal length of the foot of the unreefed mainsail along the boom = "E" in (m)
4.7
MHEAD = horizontal length of the head for square top mainsail in (m), use 0. for pinhead rig
0.1
RTWISTM = reduction of twistcurve in the middle of the mainsail in degr. -5.<RTWIST<5.,linear=0
0.
HBOOM = height of the upper face of the boom above the DWL in (m)
2.58
```

MBOOMA = maximum boom-angle when touching the shrouds, in degr.  
75.  
DMAST1 = long axis of elliptic mast section at gooseneck in (m)  
0.13  
DMAST2 = DMAST at head of unreefed mainsail, in (m)  
0.06  
AMAIN = true area of unreefed mainsail in (m2) to calculate roach  
35.4  
ASTRIG = total lateral area of standing rigging without mast in (m2) for parasitic drag  
0.48

The maximum camber of the mainsail is 18%, the profile uses the NACA-meanline. RTWISTM is defined in the same way as RTWISTJ. ASTRIG is the sum of the products length · diameter of all shrouds, backstays, and runners.

Several parameters are required to read and interpret the offset-file:

The parameter FORMAT is a description of the possible offset formats, as described in chapter 3.1. On the line beneath the chosen integer value is submitted.

FORMAT specifies data format in the offset-file: 1= point coordinates; 2= DelftShip; 3= GHS  
1  
XAXIS positive x-direction in offset-file: 1= from stern to bow; 2= from bow to stern  
2  
ZAXIS positive z-direction in offset-file: 1= from keel to deck; 2= from deck to keel  
1  
SCALE = distance at yacht in meters / numerical value of this distance in offset-file  
1e-3

XAXIS and ZAXIS tell the program in which direction the values of the coordinates in the offset file increase. The parameter SCALE allows the usage of any offset dimensions, be it a small towing tank model or a full-size ship. UliSpeed requires all dimensions in meters. In this example, the numbers in the offset file are millimeters. The numerical value of the length of the waterline  $L_{WL}$  in the offset file is 8700. The full-size yacht has an  $L_{WL}$  of 8.7 m. The scale factor is therefore  $8.7/8700 = 0.001 = 1e-3$

ZDWL z-coordinate of the DWL, in the dimension and coordinate-system of the offset-file  
0.0  
XMAST = x-coordinate of forward face of mast, dimensions & coordinate-system of offset-file  
3436.  
LEK = x-coordinate of LE keel, in the dimension and coordinate-system of the offset-file  
4055.  
LER = x-coordinate of LE rudder, in the dimension of the offset-file  
8840.

ZDWL is the z-coordinate of the designed waterline in the offset-file. It is necessary to indicate the position of the DWL, because HTACK and HBOOM are defined relative to the DWL. XMAST is the x-coordinate of the position of the forward face of the mast. LEK and LER define the position of the leading edge of the appendages. The intersections of a straight line through the leading edge of the keel and of the rudder with the bottom of the canoe body are taken for LEK and LER. The x-coordinates of these points must be submitted in the coordinate system and the dimensions of the offset-file. These four values will be converted in the same way as the coordinates in the point-file OFFS\_###.txt, by applying XAXIS, ZAXIS and SCALE.

Additional parameters are required to describe the forces and moments on the hull:

DISPL = mass displacement of the yacht in (kg), including crew and/or water ballast  
3950  
CREWRL = crew-weight on the rail (or water ballast) in (kg), = 0 if crew is in cockpit  
0  
DCOG = shift of center of gravity forward in % of LOA to trim bow down, compared to DWL  
0.  
KG = distance from keelpoint K (deepest point of CB) to center of gravity in (m)  
0.44  
RGYRA = radius of gyration in (m)  
2.5  
VSECTN = factor describes V-form of the fore section, increases side force, value: 0. - 2.  
0.80

DISPL is the weight of the yacht in kilograms, as sailed, including all equipment, water ballast and crew. The weight of the crewmembers, who are sitting on the toe rail to reduce heel, is CREWRL. This parameter can also

be used to specify the water ballast. DCOG is the shift of the center of gravity forward in x-direction, compared to the position that is defined by the DWL. The program determines first the actual waterplane for the given DISPL, parallel to the DWL. An additional positive DCOG will then trim down the bow, a negative value will raise it. If the value is higher than 3 per cent of the LOA the trim angle might be so large, that the iteration does not converge. The parameter can be used to investigate the change in boatspeed between an immersed and a dry transom.

The keelpoint  $K$  is the deepest point of the canoe body (CB). The center of gravity is often close to the DWL. In such a case,  $KG \sim T_{CB}$ . The radius of gyration around the y-axis RGYRA is required for the calculation of the added resistance in waves. It is often close to a quarter of the over-all-length.

The factor VSECTN describes the influence of the hull form on the creation of side-forces. The theory of wing sections offers a straightforward method to calculate the side-forces created by keel and rudder. Since a similar generalized theory for the complex flow around the hull is lacking, empirical correction factors must be used. VSECTN modifies the side force created by the forebody of the appended hull, depending on the form of the section. A pointed V-section with a long keel and skeg will require a value of two to match the measured force, whereas for a hull with the form of a flat soap dish a value of zero could be appropriate. A contemporary hull form with a moderately rounded forefoot is best simulated with  $VSECTN = 1$ .

Next, we define the appendages:

```
APPEND = name of the file that contains the description of the appendages: AP_XXXXX.txt
        AP_DEL33.txt
ASCALE = scale of appendages = TFIN at full size yacht in meters / value TFIN in AP_XXXXX.txt
        1.
RUDANG = rudder angle in degr. wetherhelm is positive
        2.
```

APPEND is the name of the text-file in the folder APPEND that contains the description of keel and rudder. The name must consist of eight characters plus the extension .txt. The content of this file is described in paragraph 3.4. ASCALE allows the scaling of the appendages in the same way as SCALE does it for the canoe-body. The rudder angle RUDANG that is applied by the helmsman must be guessed, since the balance around the z-axis is not computed. A value of a few degrees, not far from zero is realistic.

Two more inputs are required to calculate the resistance of the hull:

```
KS      = sand grain roughness of the antifouling in (mm), if polished = 0.
        0.05
PIPA    = drag area of propeller installation in (m2) according to ORC-formula
        0.00367      0.0152
```

Sailing yachts usually do not have a polished hull surface, but are painted with an antifouling. The roughness of the paint has an impact on the viscous resistance of the hull. The following test results are given in the literature [4] for the equivalent sand grain roughness KS:

surface	KS (mm)
hydraulically smooth (polished)	0
typical as applied antifouling coating	0.03
deteriorated coating or light slime	0.1
heavy slime	0.3
small calcareous fouling or weed	1.0
medium calcareous fouling	3.0
heavy calcareous fouling	10.0

The drag of the propeller is calculated using the ORC-formula [2]. The ORC provides a description how the equivalent drag area PIPA is determined.

The position of the anemometer is required, if you want to check your instrument readings on the water.

```
XANEMO = distance of the anemometer from the mast forward on centerline in (m)
        0.2
ZANEMO = distance of the anemometer above the mast top in (m)
        0.2
```

The next four values are the initial starting values for the trim parameters. The angles must be inserted in radian. The conversion factor is:

$$\text{angle in radian} = (\text{angle in degrees}) \cdot \pi / 180$$

It is possible to type 100. in individual places, in this case a default value will be used.

```
X1 = Sheeting angle mainsail at boom in (rad)
100.
X2 = twist mainsail in (rad)
100.
X3 = headsail camber perpendicular to forestay at clew
100.
X4 = twist headsail in (rad)
100.
```

The program uses lower and upper bounds that depend on the starting values and cannot be changed:

```
X1MIN = MAX(X1-0.1,0.)           X1MAX = MIN(X1+0.1,MBOOMA)
X2MIN = MAX(X2-0.2,0.05)        X2MAX = MIN(X2+0.2,1.5)
X3MIN = MAX(X3-0.05,0.03)       X3MAX = MIN(X3+0.05,0.18) NACA, (...0.36) parabola
X4MIN = MAX(X4-0.2,0.05)        X4MAX = MIN(X4+0.2,1.5)
```

This is done to avoid fruitless searches in irrelevant areas. It is advisable to save the downloaded input file without altering it. It can be used as a template for further input files in the future. Additional empty lines between the lines with input are not allowed.

There are three additional files in the INPUT-folder. They are called Delft\_RAW\_kyy0.2.txt, 0.25.txt and 0.3.txt. These files are needed for the calculation of the added resistance and must not be deleted or altered.

### 3.4 The file AP\_#####\_in.txt

The appendages are defined in this file. The general structure is as in USP\_###\_in.txt. The file for the Dehler 33 is named AP\_DEL33.txt. An explanation line by line follows:

```
* keel Dehler 33 full scale *
DXCOGK distance COG of keel (including bulb) to LE keel (m)
0.595
ACOFFK section area coefficient
0.648
TFIN draft of fin-keel from root (highest point) to tip, at right angle to waterplane (m)
1.6
SWEEP sweep angle of fin-keel at 1/4-cord-line in degrees
10.0
```

The first line is just comments that will not be read. DXCOGK is the positive distance in x-direction of the center of gravity of the keel to the uppermost point of the leading edge. ACOFFK is the section area coefficient, which is defined as the section area divided by chord and by max. thickness. TFIN is the draft of the fin-keel from the deepest point of the canoe-body to the tip of the keel at the trailing edge, measured at a right angle to the designed waterplane. SWEEP is the sweep angle of a straight line 25% behind the leading edge of the keel, measured against the vertical.

The following table is a description of the geometry of the keel:

Chord (m)	thickness ratio	for the given vertical position
0.8868	0.1224	at fin-root, tangential to deepest point of canoe body
0.8868	0.1224	at 19.51% TFIN down from root
0.8868	0.1183	at 38.27% TFIN down from root
0.8868	0.1171	at 55.56% TFIN down from root
0.8868	0.1210	at 70.71% TFIN down from root
0.9310	0.1252	at 83.15% TFIN down from root
1.2040	0.1384	at 92.39% TFIN down from root
1.5264	0.1261	at 98.08% TFIN down from root

For a given distance vertically downward from the root, the chord and the thickness ratio of the section must be inserted. The thickness ratio is the maximum thickness of the foil-section divided by the chord. This method of describing the geometry allows for a large variety of keel-forms that need not to have straight contours.

```
KSTYPE keel foil section type: 63 = NACA 63(2)A015, 64 = NACA 64(2)A013, 00 = NACA0012
63
```



KSTYPE defines the section-shape of the keel. Integer 63 defines the section NACA 63<sub>2</sub>A015. Integer 64 refers to the form NACA 64<sub>2</sub>A013, and 00 designates the NACA 0012 profile. The lift and drag coefficients for these foil sections were calculated with the program XFOIL [5] with natural transition as a function of different Reynolds-numbers and different thickness ratios. If the section of the keel does not match exactly the NACA profile family, the position of the maximum thickness should be the guidance for the choice. NACA 64 has it at 40%, NACA 63 at 35% and NACA 0012 at 30% of the chord.

Three parameters describe a ballast bulb, if provided:

```
BULBL lenght in (m) of additional ballast bulb at tip of fin, without bulb type 0.
0.
BULBW width of ballast bulb in (m)
0.
BULBH height of ballast bulb in (m)
0.
```

The description of the rudder is similar to the keel. The first line is again just a comment. Two additional measurements are required for twin rudders. DYRUD is the distance of the top of the rudder from the symmetry-plane, INCLIN the inclination-angle between the rudderstock and the symmetry-plane.

```
* rudder Dehler 33 *
DYRUD for twin rudders = y-distance of root from centerline in (m), for one rudder = 0.
0.
INCLIN for twin rudders = inclination to vertical in (deg.), for one rudder = 0.
0.
TRUD rudder span at TE, from root at hull to tip, at right angle to centerline (m)
1.344
DXCOGR distance COG of rudder to LE rudder (m)
0.372
SWEEPR sweep angle 1/4-cord-line of rudder relative to vertical on centerline in degrees
20.3
CURUD chord at upper end of leading edge , parallel to centerline (m)
0.454
CLRUD lower chord at tip, parallel to centerline (m)
0.367
TCURD thickness ratio of upper section at top (-)
0.16
TCLRD thickness ratio of lower section at tip (-)
0.11
ACOFFR section area coefficient
0.6648
RSTYPE rudder foil section type: 63 = NACA 63(2)A015, 64 = NACA 64(2)A013, 00 = NACA0012
64
```

TRUD is measured at the trailing edge, at right angle to DWL for one rudder and at right angle to centerline for twin rudders. Since the upper part of the rudder follows normally the contour of the hull, the chord at the upper end of the leading edge of the rudder CURUD is used for its definition. The other parameters are analogous to the keel-parameters.

#### 4 RUNNING THE PROGRAM

When opening UliSpeed.exe the window on the next page will appear and will ask you for the identifier of the input file (depending on the setting of your command prompt options, the background color might be black). Here in the example the identifier for the file was "d33". The program will use the initial parameters X1-X4 and solve the equations for the equilibrium of forces and moments. The result is printed in one line. X1, X2 and X4 are displayed in radians. Phi is the heel angle in degrees, V<sub>boat</sub> is the boat speed in knots and F<sub>merit</sub> is a figure of merit that is gained from V<sub>boat</sub> by multiplication with a penalty for spikes and the waviness of the induced velocities. The last figure in the line is the number of spikes. The solution is usually not unique. There might be several possible solutions for a given set of the parameters X1-X4. If the code does not find a converged solution, it is often sufficient to alter the starting values only slightly. If there are too many spikes, it often helps, to increase the sheeting angles. At large true wind angles (> 90°) spikes cannot be avoided. If you have a converged solution, you can select the number of iterations to optimize the trim parameters. If you type "0" the current result will be used for the output files. In case of optimization, the code will maximize the figure of merit.

```

C:\Users\Uli\Documents\Visual Studio 2019\Projekte\UliSpeed_2.1\Release\UliSpeed_2.1.exe
*****
*           UliSpeed 2.1           *
* Copyright (C) 2024 Ulrich Remmlinger *
* This is research code, commercial usage *
* and distribution not allowed. You run *
* this program at your own risk. The author *
* accepts no warranty and no liability. *
* For more details see www.remmlinger.com *
*****

If you agree to the above conditions,
type 3 characters ### and press ENTER
input file INPUT/USL_###_in.TXT will be used
d33

HTACK in offset-file = 0.800 instead of 1.180
sections extrapolated to level of HTACK

      X1      X2      X3      X4      Phi  Vboat(kt)  F-merit spikes
0.030000  0.298907  0.040904  0.552330  17.167  5.9840  5.9054  0 new best value

max. number of iterations to optimize the trim parameters, 500 is sufficient:
400

```

The screenshot at the end of the run is depicted in the following picture. Each line shows the parameters X1–X4 that were proposed by the optimizer IFFCO and the results Phi, Vboat and F-merit. The printed results for the optimum at the end are in addition the leeway Delta, the sinkage Ztrimm, the longitudinal trim angle Ptrimm, the apparent wind angle AWA, the sail force Fx\_aero in x-direction and the side force FS\_aero. The sail trim parameters at the optimum X1–X4 are listed at the end. The result is the optimal flying shape of the sails. The shape is for the stretched sails under load.

```

C:\Users\Uli\Documents\Visual Studio 2019\Projekte\UliSpeed_2.1\Release\UliSpeed_2.1.exe
0.028599 0.297271 0.044626 0.556303 no convergence
0.028599 0.297252 0.044623 0.556303 17.332 5.9910 5.9200 0
0.028599 0.297252 0.044629 0.556303 17.332 5.9910 5.9200 0
0.028599 0.297252 0.044626 0.556283 17.334 5.9929 5.9221 0
0.028599 0.297252 0.044626 0.556322 17.332 5.9910 5.9200 0
0.000000 0.098907 0.044385 0.352330 spreader intrudes into headsail
0.000000 0.098907 0.044505 0.352330 spreader intrudes into headsail
0.000000 0.098907 0.044565 0.352330 spreader intrudes into headsail
0.000000 0.098907 0.044596 0.352330 spreader intrudes into headsail
0.000000 0.188919 0.044611 0.451507 22.284 6.1285 1.0546 4
0.000000 0.243086 0.044618 0.503905 no convergence
0.012996 0.270169 0.044622 0.530104 19.159 6.0608 5.5169 0
0.021467 0.284873 0.044624 0.544328 18.169 6.0253 5.5750 0
0.026141 0.292987 0.044625 0.552176 17.611 6.0030 5.7331 0
0.027785 0.295839 0.044625 0.554936 no convergence
0.028517 0.297111 0.044626 0.556166 no convergence
0.028590 0.297238 0.044626 0.556289 17.335 5.9929 5.9221 0
0.028576 0.297252 0.044626 0.556303 no convergence
0.028599 0.297252 0.044626 0.556303 17.334 5.9929 5.9221 0
0.028587 0.297232 0.044626 0.556303 17.335 5.9929 5.9221 0 new best value
0.028587 0.297271 0.044626 0.556303 17.334 5.9929 5.9221 0
0.028587 0.297252 0.044623 0.556303 17.334 5.9929 5.9221 0
0.028587 0.297252 0.044629 0.556303 17.333 5.9910 5.9200 0
0.028587 0.297252 0.044626 0.556283 17.333 5.9910 5.9200 0
0.028587 0.297252 0.044626 0.556322 17.334 5.9929 5.9221 0
0.028587 0.297232 0.044626 0.556303 17.335 5.9929 5.9221 0

F_merit = 5.92212142186135
V_boat = 5.99293359598304
Phi = 17.3349810506169
Delta = 3.43517649704396
Z trimm = 4.466665053593781E-002
P trimm = 1.599053408970736E-002
AWA = 23.2536319185762
Fx_aero = 525.299056595375
FS_aero = 2019.38496336205
Ispike = 0
PENALTY = 1.181594506055486E-002

IFFCO found this optimum:
X1 = 2.858737303930559E-002
X2 = 0.297232415340079
X3 = 4.462565670309432E-002
X4 = 0.556302553721042
IFFCO used 410 function evaluations.
execution time 213.53 minutes
press Enter to quit

```

## 5 THE OUTPUT FILES

There are three files in the folder USP. The file OUT\_d33.TXT repeats the results that were printed on the screen plus more information about the hull in the heeled and trimmed attitude. The following is an example:

All results calculated with UliSpeed 1.4  
for details see [www.remmlinger.com](http://www.remmlinger.com)

\* Dehler 33 \*

Hull geometry defined in: OFFSETS/OFFS\_D33.txt  
Appendages defined in: APPEND/AP\_DEL33.txt  
Input data in file : INPUT/USL\_d33\_IN.txt

hull properties in heeled attitude with sinkage and trim:

displacement (kg) = 3950.  
crew on rail (kg) = 0.  
waterline length (m) = 9.259  
beam in waterplane (m) = 2.286  
draft of canoe body (m) = 0.492  
COG aft of LE keel (m) = 0.865  
trimming moment (Nm) = 0.  
in upright condition, flat water, zero speed:  
maximum draft (m) = 2.022

The position of the center of gravity is given relative to the leading edge of the keel, which is defined by LEK. The trimming moment in Nm is the one, which is required to achieve the shift that DCOG prescribes. If two men (80 kg each) move three meters forward from the center of the cockpit, it would create a trimming moment of  $2 \cdot 80 \text{ kg} \cdot g \cdot 3 \text{ m} = 4800 \text{ Nm}$ . If they move aft, the moment is negative.

The sea state is described by the significant wave height and the peak period. The value for the natural turbulence in the water is used for the computation of the boundary-layer along the hull.

sea state:  
V wind true = 10.0 kts.  
TWA = 41.0 deg.  
modified JONSWAP spectrum  
wave height = 0.22 m  
peak period = 2.06 s  
turbulence = 0.29 %

The rig properties repeat the input values. The position of the jib-sheet-car on deck is described by the angle between the centerline and a line from the forestay chainplate to the jib-car and by its distance to the centerline.

rig properties:  
main hoist = 100.0 %.  
Jib profile = NACA  
LP Jib = 142.0 %  
CAMDIS = 3  
position of jib-car on deck:  
sheet. angl = 11.0 deg.  
to centerln = 1.12 m

$F_x$  aero is the aerodynamic force in the direction of the centerline.  $F_y$  aero is the side force at right angle to  $F_x$  and to the mast.  $F_S$  aero is the side force parallel to the waterplane.

The apparent wind angle AWA is given at the combined geometric center of the sails.

sinkage is the movement of the center of gravity relative to the surrounding water surface in the vertical direction. The pitch-angle is measured between the x-axis and the horizon.

$F_x$  aero = 525.299 N  
 $F_y$  aero = 2079.643 N  
 $F_S$  aero = 2019.385 N  
heel.moment = 16235.72 Nm  
V boat = 5.993 kts.  
AWA = 24.107 deg.  
heel angle = 17.335 deg.  
leeway = 3.435 deg.  
rudder angl = 2.0 deg.  
sinkage = -0.043 m  
draft increase = +  
pitch-angle = -1.090 deg.  
bow up = +

The following drag components are the components in the direction of the leeway, not in the direction of the x-axis. These are the viscous resistance of the canoe body, the induced resistance caused by the side force produced by the canoe body, the drag force of the appendages including induced drag, the wave making (= residual) resistance of the hull, the additional resistance in waves and the propeller drag. If a ballast bulb is fitted, this drag will also be listed. The units are Newtons.

VMG is the velocity made good, head on to the direction of the true wind.

```
drag components in the direction of travel:
Rviscous cb =      337.5  N
Rinduced cb =       7.1  N
R append   =     112.7  N
R residual =     117.5  N
ad in waves =      56.8  N
R propeller =      14.1  N

VMG          =      4.279 kts.
```

The quality of convergence can be judged by the number of spikes and by the penalty function, the lower, the better.

```
optimization of trim parameters:
F_merit      =      5.922
Ispike       =          0
PENALTY      =     0.1182E-01
```

The sail trim parameters are as explained for the input file

```
Sail trim parameters in rad
X1 =      0.0286
X2 =      0.2972
X3 =      0.0446
X4 =      0.5563
```

```
Sail trim parameters in deg.
sheet.anagl. main =    1.64 deg.
twist main       =   17.03 deg.
camber jib @clew =    4.46 %
twist jib        =   31.87 deg.
```

The shape of the mainsail, including roach, can be calculated from the following equation for the chord  $c$ :

```
shape of the mainsail: chord c can be calculated from:
c = SQRT(A*(B-z))+C
A =      3.46638
B =     14.63606
C =     -2.42279
z = height above boom in meters
```

The information about the wind at the mast top is helpful, if you want to compare the measured speed of your boat on the water with the predictions from UliSpeed. The anemometer at the mast top does not indicate the exact apparent wind, because the circulation of the sails distorts the onset flow. Since UliSpeed uses the Biot-Savart-law, it is possible to calculate the apparent wind at the anemometer. If you want to compare your measurements on the water, you should insert for  $VTW10$  and  $BETATW$  in the input file values that produce calculated values at the masthead, which match your instrument readings. It is assumed, that the anemometer heels like the boat.

```
apparent wind, measured with anemometer at masttop
components at right angle to the mast
indicated windspeed 15.20 kts
indicated direction 28.70 deg
```

The file `Vi_d33.TXT` contains a listing of the induced velocities  $u_i$  and  $w_i$  for the 31 panels of the headsail and the 31 panels of the mainsail. It should be checked for spikes and waviness. In the file `Coeff_d33.TXT` one can find the coefficients and aerodynamic characteristics as a function of the height in  $z$ -direction. This distribution gives an insight into the flow around the sails. The listed sheeting angles as a function of  $z$  are measured at a right angle to the mast for the mainsail and at a right angle to the forestay for the headsail. The camber is measured along the chord in the direction of the apparent wind. There is also a description of the apparent wind (angle and speed) as a function of  $z$ . Excel can read the text-files and one can use the data to create diagrams that explain the flow. The file `D33.xlsx` shows possible interpretations. These excel-diagrams should always be

created because the program is not a foolproof tool that can be trusted blindly. It requires the knowledge of an aerodynamicist to interpret the results. The description of the lifting-line method in [6] points to possible failures and weaknesses.

It should also be kept in mind, that the 2D-coefficients that are used to calculate the sail forces were determined with XFOIL [5] for ideal conditions. In real life, the sails will have wrinkles and the profile will not exactly follow the optimal shape. Small disturbances at the surface can already lead to local flow separation. The boat speed might be smaller than the computed value.

When I developed the program, my emphasis was on speed and simplicity, not on nice graphics. Without a graphical interface, it might be tedious to create the input file for the first time, but it saves a lot of time afterwards, when you only want to test small changes.

Good luck with your computations. Feedback reaches me at [ulrich@remmlinger.com](mailto:ulrich@remmlinger.com)

## 6 REFERENCES

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## 7 CAD-FILE

If you require a CAD-file of your sails, you can write me an e-mail. I can create a point-file or an IGES-file of the sails with optimal shape that can be read by most CAD-programs. The following pictures are screenshots of the Pogo 40 S2 at a true wind angle of  $40^\circ$  and wind speed 16 knots. The CAD-Program is Rhino5. The lines on the sails are sections in the direction of the streamlines.

