Corbin 39 Study – Theoretical Analysis - Initial Results re Weather Helm

Study by Jean-Francois Masset, introduction by David Sharman rev 12th April 2020

Working document

This is a working document setting out the interim results of an ongoing study into various aspects of the Corbin 39. We think it is worthwhile communicating results as they arise so as to obtain feedback from the Corbin 39 community. The initial focus of the study is into weather helm. Future areas of interest are hoped to include loading and trim, stability, sailing performance and seaworthiness, and to document hull form and its hydrostatics.

The theoretical results to date are in agreement with the practical observations of Corbin owners.

Because this is a working document it may contain errors, and will change.

Jean-Francois Masset and Gene-Hull

Most of this study is carried out by Jean-Francois Masset who is a retired naval architect who has most generously given his time and knowledge to assist the Corbin 39 community. He has developed a design programme called "Gene-Hull" in a spreadsheet format that is ordinarily used for early stage yacht design when there are a lot of design options under consideration, before down-selecting into detailed studies of a preferred design. However in this study Gene-Hull is being repurposed to analyse the many different sail & spar layouts that the Corbin 39 was built with, and then to theoretically assess the performance and the development options open to each layout.

We owe Jean-Francois many thanks for his most kind support to our community.

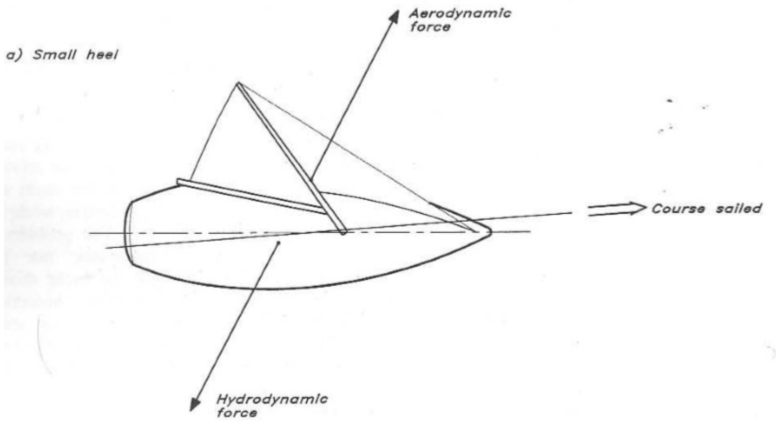
The Corbin 39

The Corbin 39 was a cruising yacht of approximately 39' length, of which approximately two hundred hulls were moulded in Canada during a ten-year period from 1979 - 1989. Most were completed by the owners, though some were fully constructed by the yard, and as a result there is unusual variety of which the main configurations are described. The Corbin 39 fin keel is intermediate in length between a full-length keel and a slender racing fin keel. In the early years it was available in its "mk1" form as a single-masted cutter with the mast located at an aft mast position, or as a two-masted ketch with the mainmast located at a forward mast position. There is 32" between these two mast positions. The cutter was either a short mast version with a 46' mast, or a 51' tall mast version. The mk1 cutters tended to exhibit weather helm, though the mk1 ketch did not. After a factory fire a "mk2" version was released with a 49' mast in the forward mast position and a 36" bowsprit, which did not suffer weather helm. Many of the mk1's have had one or more changes made to them, including: the addition of a bowsprit; shortening of the boom; or underbody modifications such as skeg changes. However many unmodified mk1's also exist and owners or prospective buyers would like to know the benefits of each option, or whether to make no change – after all even an unmodified Corbin 39 mk1 is still a very nice and attractive yacht, many of which have circumnavigated safely and pleasureably.

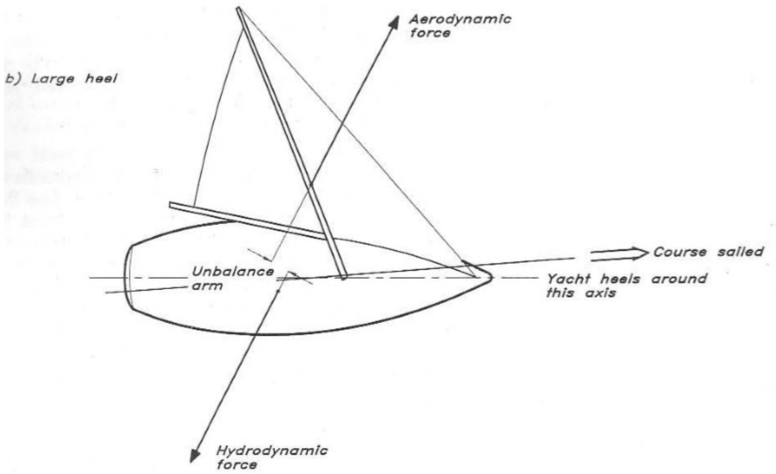
Weather helm

Weather helm is the tendency of sailing vessels to turn towards the source of wind, creating an unbalanced helm that requires pulling the tiller to windward (i.e. 'to weather') in order to counteract the effect. More explanation, thanks to L.Larsson and R.Eliasson analysis and figures within their book « Principles of yacht Design » :

Under equilibrium, the hydro and aero forces resulting forces must act along the same line :



If the yacht heels more, due to the height of the aero forces / rotation axis of the boat heeling, the aero forces moves more leeward while the opposite is true for the hydro forces moving a bit winward, causing the forces to act on different lines and creating a turning moment in horizontal projection :



>>> Then, an extra hydro force provided by the rudder is required to recover the equilibrium, i.e. an extra lift at the cost of an extra drag. Moreover, upwind when the boat speed is already close to its maximum, the aero force due to more windspeed can increase more than the corresponding hydro force due boatspeed little or no increase. Up to a situation out of control when the rudder wing stalls and cannot provide more lift.

That said, weather helm is generally less troublesome than the opposite lee helm because it is a relatively safe phenomenon that will cause a sailing vessel to stop safely, whereas lee helm can cause an uncontrollable and dangerous rapid gybe. Many sailors consider moderate weather helm to be desirable.

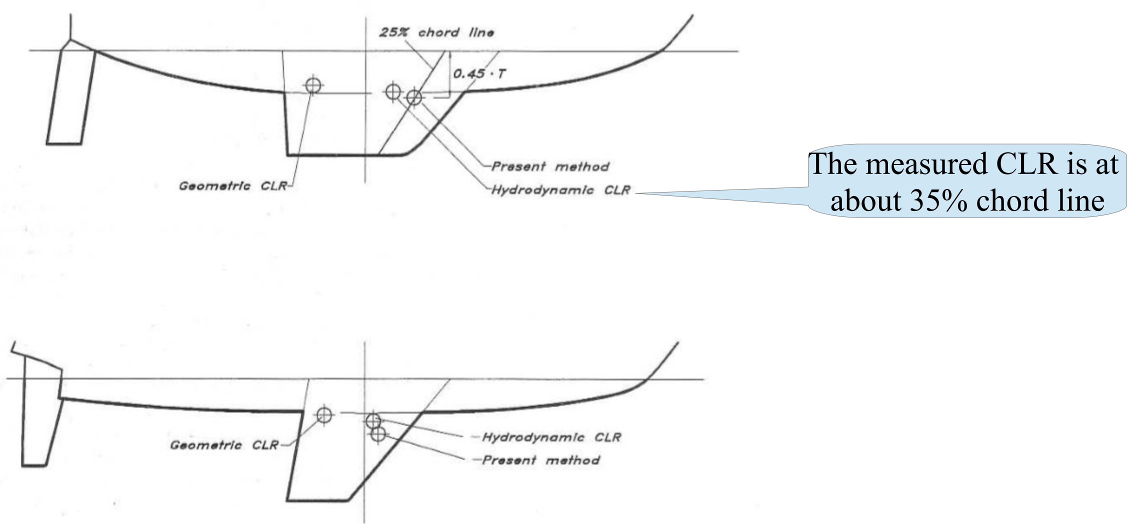
For a yacht like a Corbin 39 weather helm is considered excessive if there is a need to reef the mainsail early, in order to remain ‘balanced’, i.e. at approximately 15-knots windspeed as opposed to the more normal 20-knots windspeed. Up to this point the weather helm can be countered by increasing the rudder angle but this will also increase drag and slow the boat down.

Fundamentally weather (or lee) helm is in relation with the initial differential in position (at zero$^+$ heel angle) between the center of effort (“CE”) of the sail plan to the centre of lateral resistance (“CLR”) of the hull. When the centre of effort of the sail plan is in front of the centre of lateral resistance of the hull this is referred to as the CE “leading” the CLR, and this is recommended to cope with the evolution with heel described here above. This initial offset is called the « Lead » and it is a design parameter.

Interpreting study results

In this study the key metric to observe is the ratio of the Lead to the length of the waterline, and this is quoted as a percentage, i.e. “% Lwl”.
The reference text for yacht design that we are referring to is“Principles of Yacht Design” by Lars Larsson & Rolf Eliasson, 2nd edition (“PYD”). They recommend in PYD that for fin-keel yacht with a masthead sloop rig the lead %Lwl should be in the range of 5% – 9% so as to keep weather helm in a preferred range. This recommendation holds true for analysing cutters with an inner staysail, and also ketches provided that certain adjustments are made when assessing the effectiveness of the mizzen. To analyse the Corbin 39 there are two slight adaptations made to the PYD method :

• As it is an heavy fin-keel cruising yacht corresponding to the shape in the middle of the PYD Fig. 8.2 (here below), Jean-Francois takes into account the measurement done leading to a CLR at about 35% chord line instead of 25 % for a racer fin-keel one :



• Within the PYD method, Jean-Francois extends the keel to the real waterline for 14,000 kg (30,864 lbs), being a typical working displacement for a cruise. This would be the actual “hook weight” we would expect to be shown on a crane if the yacht were to be lifted out of the water in the stored, fuelled, spared condition with water tanks and crew possessions etc.

In the results, if the Lead %Lwl falls below 5% then this is an indication that weather helm may begin to become excessive. The closer to 0% the more problematic weather helm is likely to be, or in the extreme it could become negative.
On the other hand, the PYD method for CE is elementary, just considering the geometrical centers of the “100% sail triangle areas” for each of the configurations. For the mainsail this is simply the triangle area from the boom to the masthead. For the foresails this is the triangle area formed by the forestay and the mast. For the ketch, PYD recommended to consider 50% of the Mizzen triangle area. The justification given by PYD for such method for CE and CLR and the Lead = CE – CLR is just that a large amount of experiences has been screened with it and allowing reliable statistics.

This does not take into account any real-world sail cutting into (say) a “yankee”, or a 135% genoa. It is normal to carry out a first analysis of any design in this way so as to have a consistent baseline for comparison. It is worth considering that using a large genoa will tend to shift the centre of effort (CE) of the sails aft, and reduce the lead (%Lwl).
As well as considering the effect of various changes such as shortening boom, adding bowsprits, the studies also consider the effect of a mast rake, up to 1,3°, actually to cover the uncertainty of the mast real adjustment. In general terms raking the mast aft (+ve rake) will reduce the lead.

Keep it in proportion

Weather helm should not be a consideration that is disproportional to reality. It's not that bad and you only notice it on a beat or on a reach at about 15 knots windspeed and over (depending on your sails and on how you trim them), at which time it's easy to put in a reef from the cockpit. Using high cut yankees may help. Also, the mast in the aft position is an opportunity to deploy a larger genoa and gain speed. Aesthetically many people prefer a Corbin without a bow sprit. Even those who like the look of a bowsprit will find that some marinas will charge a lot more; manoeuvring in tight quarters is much more stressful than putting in a reef once in a while and a bowsprit may limit your choice and ease of using a modern anchor. Potential Corbin purchasers, by focusing on the weather helm issue, might overlook some crucial points that may be much more important to enjoying boat ownership. Including acquisition cost, and the number of available boats.

The worst case is that you reef at 15 kts (7.7 m/s) windspeed rather than at 20 kts (10.3 m/s) if you are close hauled, how hard is that – especially if you are set up for in-cockpit slab reefing (or in-mast furling)? And by those windspeeds you are achieving hull speed through water in any case, so the boat can't go appreciably faster, just tip over more. In many parts of the world you will seldom be sailing close hauled for an appreciable amount of time in that probability 'slice'. As an illustration of this, a cumulative probability calculation for a location with a average windspeed of 5m/s (10 kts) which would be a typical moderately exposed coast, suggests the cumulative probability of wind below 20 kts is 97%, whereas the cumulative probability of wind below 15 kts is 83%. What this means is that 14% of the time an unmodified mk1 cutter might need to reef early if beating upwind versus a mk2. If you take the view that some of that time you'd be reaching or running (in which case weather helm is not relevant), and some of that time you'd head ashore (etc) in expectation of further worsening weather, it is not that significant, maybe 5% extra time reefed.

As an indication of the cost of some of the changes discussed, the following budget approximations for retrofits have been provided by Corbin owners:

i) Set up a Corbin for quick & easy slab reefing of the main entirely from the aft (or centre) cockpit: approx USD 500 + labour.

ii) Add a heavy duty platform-style bowsprit and anchor platform (as per the mk2) extending 36" forwards, and extending 36" aft along the hull sides. Including headstay changes, bobstay, pulpit changes, etc : approx USD 8,000 + labour.

Iii) Ad a pole-style bowsprit : still under discussion, perhaps USD 3,500 – 4,000.

iv) Shorten a boom by 36" : approx USD 500 + labour, but will also require a new or recut mainsail.

Note that the above costs do not include any new or recut sails. As a budgeting guide a new set of performance/cruising sails in Dacron 360/380 for a Corbin would be approximately USD 11,200 comprising fully battened Dacron 360 main (USD 3,570); furling 120% genoa in Dacron 380 (USD 3,500); working staysail in 360 AP (8.4oz) (USD 1,400); and cruising chute & snuffer in 1.5 oz 65g nylon (USD 2,800).

So keep things in proportion – after all is said and done, a mk1 Corbin is in every respect a very nice boat indeed. As with all things in sailing it is important to keep in mind the smiles per $.

Layout of a results page

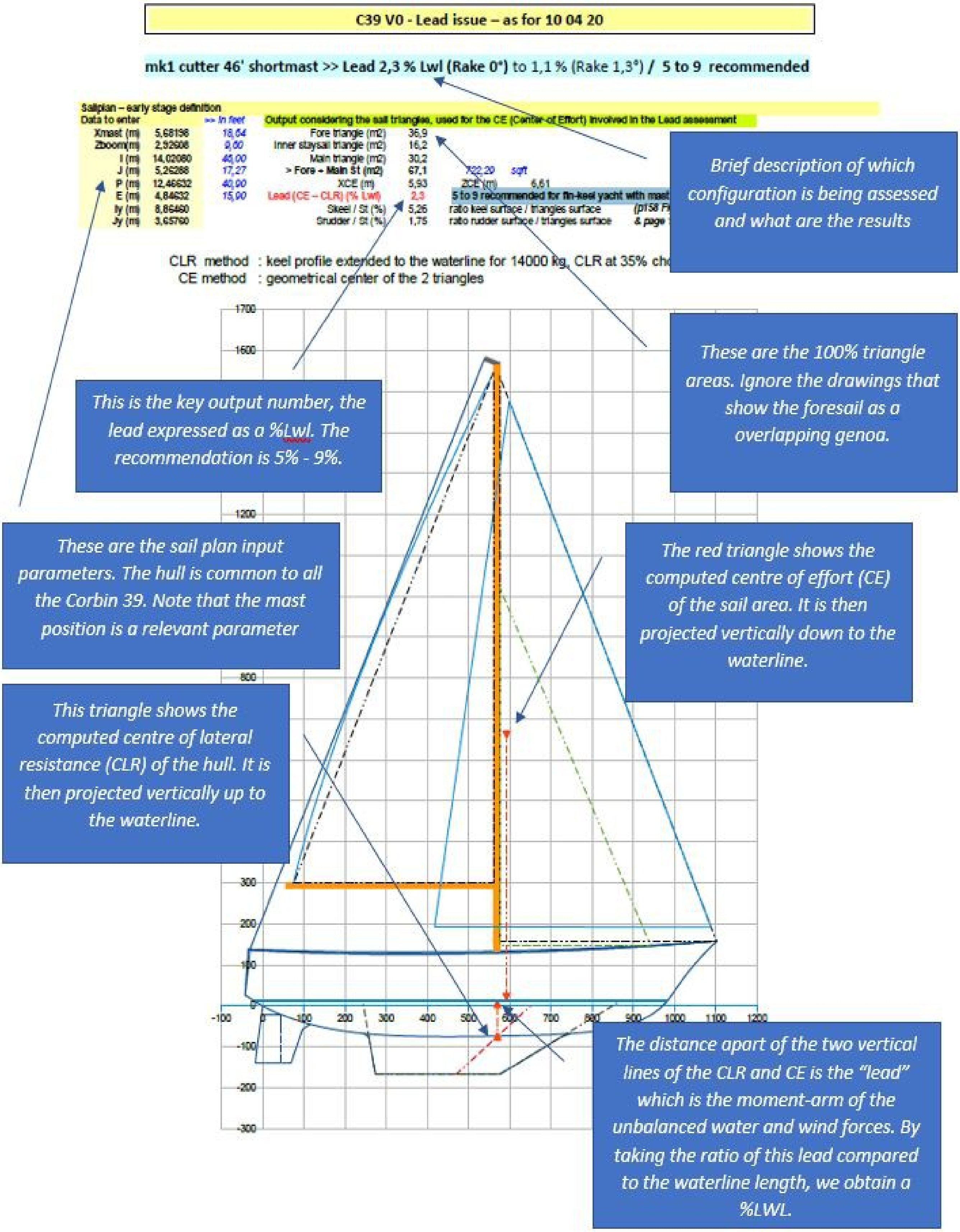


Table of principal results

Case #	Configuration	Modification	Sails triangles at stake (m2)	Lead (unraked)	Lead (raked at 1,3°)	Comment
				5% to 9% Lwl recommended		
1	mk1 cutter 46' shortmast		67,1	2,3%	1,1%	>>> to reef first the mainsail when necessary
2	mk1 cutter 51' tallmast		73,0	2,9%	1,6%	>>> to reef first the mainsail when necessary
3	mk1 ketch 46' > Mizzen high		68,6	4,0%	2,8%	Method : Mizzen taken at 50% >>> optimal by light wind
	> Mizzen off		57,7	9,1%	**7,9%**	>>> optimal by breeze
4	mk2 cutter 49' bow-sprit	mast ahead by 32''	76,7	9,2%	**7,9%**	>>> a bit lee helm by light wind but optimal by breeze
5	mk1 cutter 46' shortmast	Bow-sprit 36''	73,7	**5,5%**	4,3%	>>> rather good modification
6	mk1 cutter 51' tallmast	bow-sprit 36''	80,3	**6,1%**	4,8%	>>> good modification
7	mk1 cutter 51' tallmast	Boom shortened by 36''	66,6	**5,9%**	4,6%	>>> good modification + even better with a mainsail new cut advancing the CE.
8	mk1 cutter 46' shortmast	Bow-sprit 36'' & bow tack used for the inner staysail	73,7	**5,5%**	4,3%	Same as #5 for the Lead
9	mk1 cutter 51' tallmast	Bow-sprit 36'' & bow tack used for the inner staysail	80,3	**6,1%**	4,8%	Same as #6 for the Lead

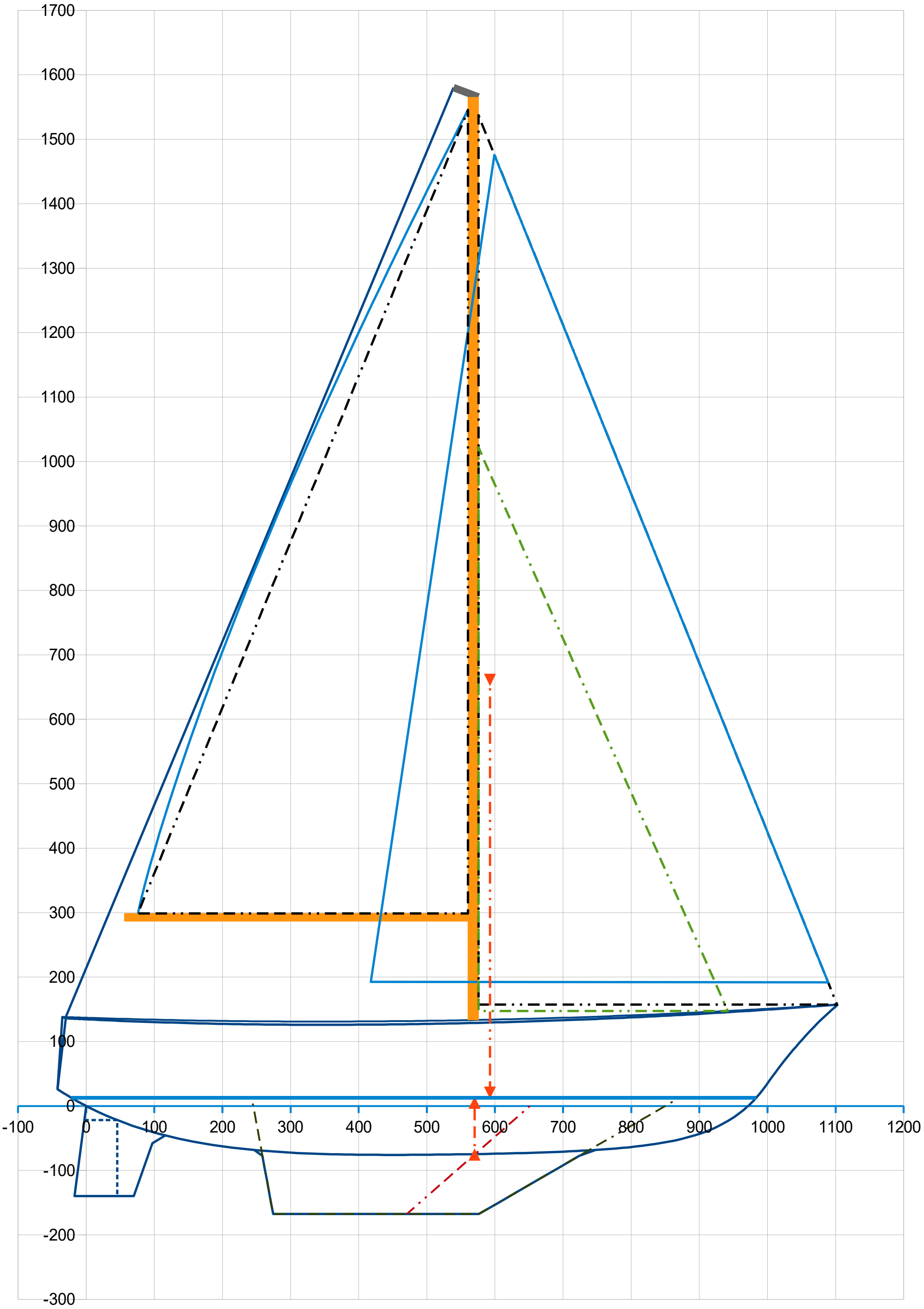
Details case by case :

mk1 cutter 46' shortmast >> Lead 2,3 % Lwl (Rake 0°) to 1,1 % (Rake 1,3°) / 5 to 9 recommended

Sailplan – early stage definition

Data to enter		>> in feet	Output considering the sail triangles, used for the CE (Center of Effort) involved in the Lead assessment				
Xmast (m)	**5,68198**	*18,64*	Fore triangle (m2)	36,9			
Zboom(m)	**2,92608**	*9,60*	Inner staysail triangle (m2)	16,2			
I (m)	**14,02080**	*46,00*	Main triangle (m2)	30,2			
J (m)	**5,26288**	*17,27*	**> Fore + Main St (m2)**	**67,1**	*722,29*	*sqft*	
P (m)	**12,46632**	*40,90*	XCE (m)	5,93	ZCE (m)	6,61	
E (m)	**4,84632**	*15,90*	**Lead (CE – CLR) (% Lwl)**	**2,3**	**5 to 9 recommended for fin-keel yacht with masthead sloop (in PYD (Larsson- Eliasson)**		
Iy (m)	**8,86460**		Skeel / St (%)	5,26	ratio keel surface / triangles surface		***(p158 Fig. 8.2 center : heavy fin-keel cruising yacht***
Jy (m)	**3,65760**		Srudder / St (%)	1,75	ratio rudder surface / triangles surface		***& page 162 recommandations)***

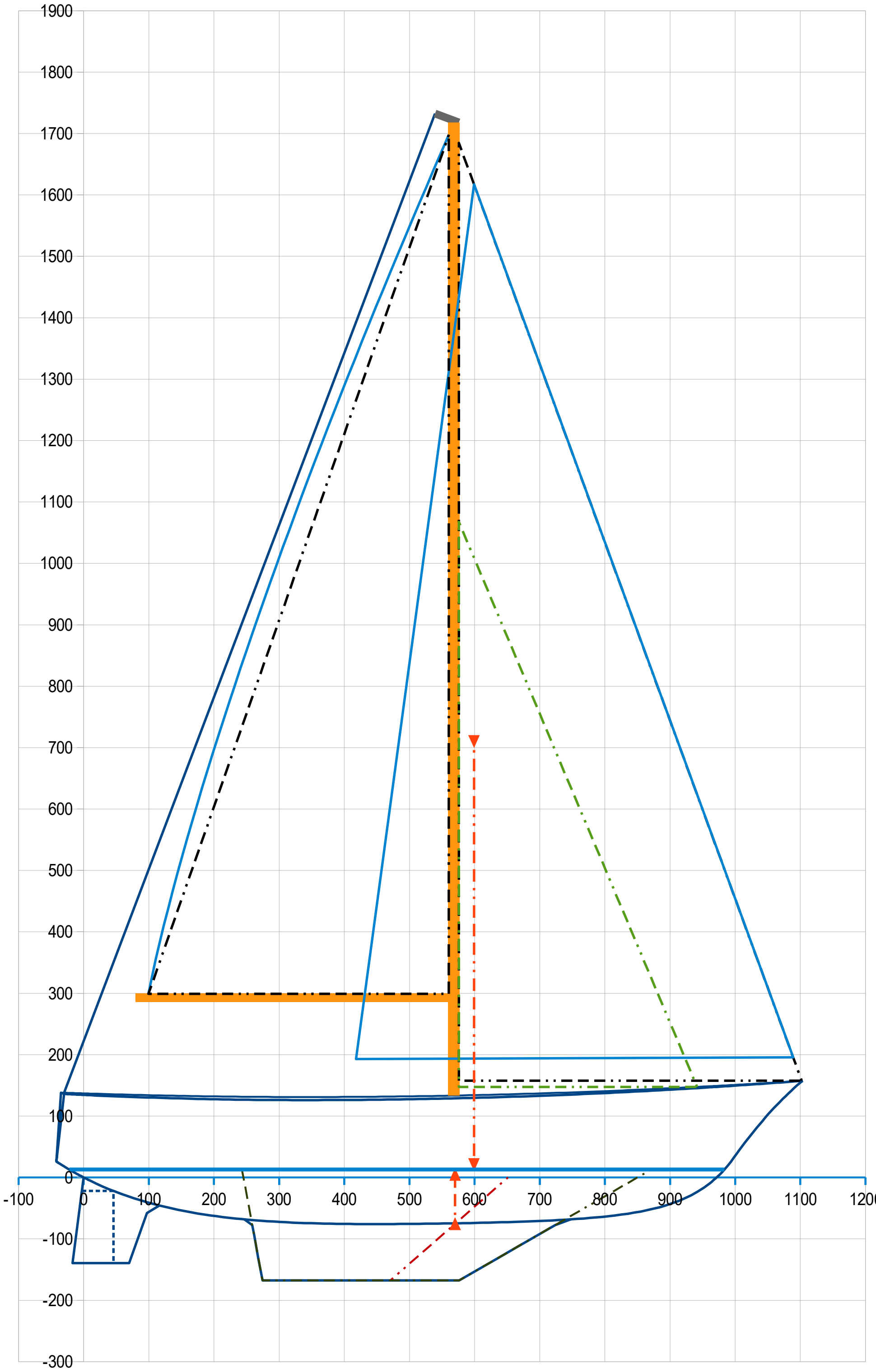
CLR method : keel profile extended to the waterline for 14000 kg, CLR at 35% chord and 45% draft oa
CE method : geometrical center of the 2 triangles



mk1 cutter 51' tallmast >> Lead 2,9 % Lwl (Rake 0°) to 1,6 % (Rake 1,3°) / 5 to 9 recommended

Sailplan – early stage definition

Data to enter		>> in feet	Output considering the sail triangles, used for the CE (Center of Effort) involved in the Lead assessment				
Xmast (m)	5,68198	18,64	Fore triangle (m2)	40,8			
Zboom(m)	2,92608	9,60	Inner staysail triangle (m2)	17,0			
I (m)	15,49400	50,83	Main triangle (m2)	32,2			
J (m)	5,26288	17,27	**> Fore + Main St (m2)**	**73,0**	785,98	sqft	
P (m)	13,99032	45,90	XCE (m)	5,99	ZCE (m)	7,10	
E (m)	4,61010	15,13	Lead (CE – CLR) (% Lwl)	2,9	**5 to 9 recommended for fin-keel yacht with masthead sloop (in PYD (Larsson- Eliasson)**		
Iy (m)	9,32180	30,58	Skeel / St (%)	4,84	ratio keel surface / triangles surface		*(p158 Fig. 8.2 center : heavy fin-keel cruising yacht*
Jy (m)	3,65760	12,00	Srudder / St (%)	1,60	ratio rudder surface / triangles surface		*& page 162 recommandations)*



mk1 ketch 46' >>

ketch configuration : Lead 4,0 % Lwl (Rake 0°) to 2,8 % (Rake 1,3°) **/ 5 to 9 recommended**

sloop configuration : Lead 9,1 % Lwl (Rake 0°) to 7,9 % (Rake 1,3°) **/ 5 to 9 recommended**

Sailplan – early stage definition

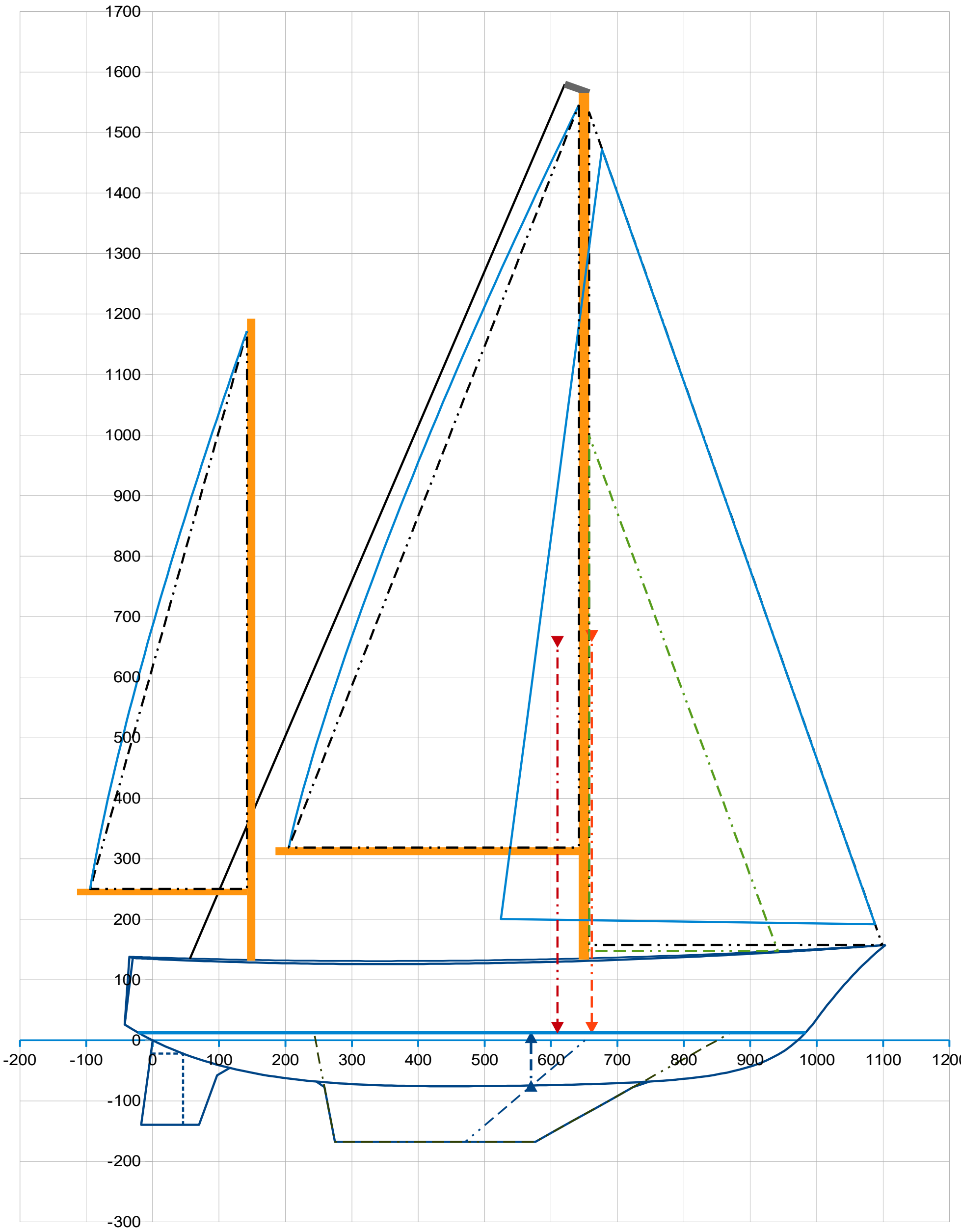
Data to enter		>> *in feet*
Xmast (m)	**6,49500**	*21,31*
Zboom(m)	**3,12420**	*10,25*
I (m)	**13,98016**	*45,87*
J (m)	**4,41960**	*14,50*
P (m)	**12,26820**	*40,25*
E (m)	**4,36880**	*14,33*
Iy (m)	**8,63600**	*28,33*
Jy (m)	**2,84480**	*9,33*
Ketch ?	**1**	
Xmast (m)	**1,48300**	*4,87*
Zboom(m)	**2,45100**	*8,04*
P (m)	**9,22000**	*30,25*
E (m)	**2,36200**	*7,75*

Output considering the sail triangles, used for the CE (Center of Effort) involved in the Lead assessment

Fore triangle (m2)	30,9			
Inner staysail triangle (m2)	12,3			
Main triangle (m2)	26,8			
Mizzen triangle (m2)	10,9			
Sloop triangles St (m2)	**57,7**	*620,99*	*sqft*	
XCE (m)	6,61	ZCE (m)	6,68	
Lead (CE – CLR) (% Lwl)	**9,1**	**5 to 9 recommended for fin-keel yacht with masthead rig**		
Ketch triangles St (m2)	**68,6**	*738,20*	*sqft*	
XCE (m)	6,10	ZCE (m)	6,58	
Lead (CE – CLR) (% Lwl)	**4,0**	**5 to 9 recommended for fin-keel yacht with masthead rig**		
Skeel / St (%)	5,59	ratio keel surface / triangles surface		
Srudder / St (%)	1,85	ratio rudder surface / triangles surface		

CLR method : keel profile extended to the waterline for 14000 kg, CLR at 35% chord and 45% draft oa

CE method : geometrical center of the 2 triangles + (if any) mizzen triangle at 50%



mk2 cutter 49' bow-sprit >> Lead 9,2 % Lwl (Rake 0°) to 7,9 % (Rake 1,3°) **/ 5 to 9 recommended**

Sailplan – early stage definition

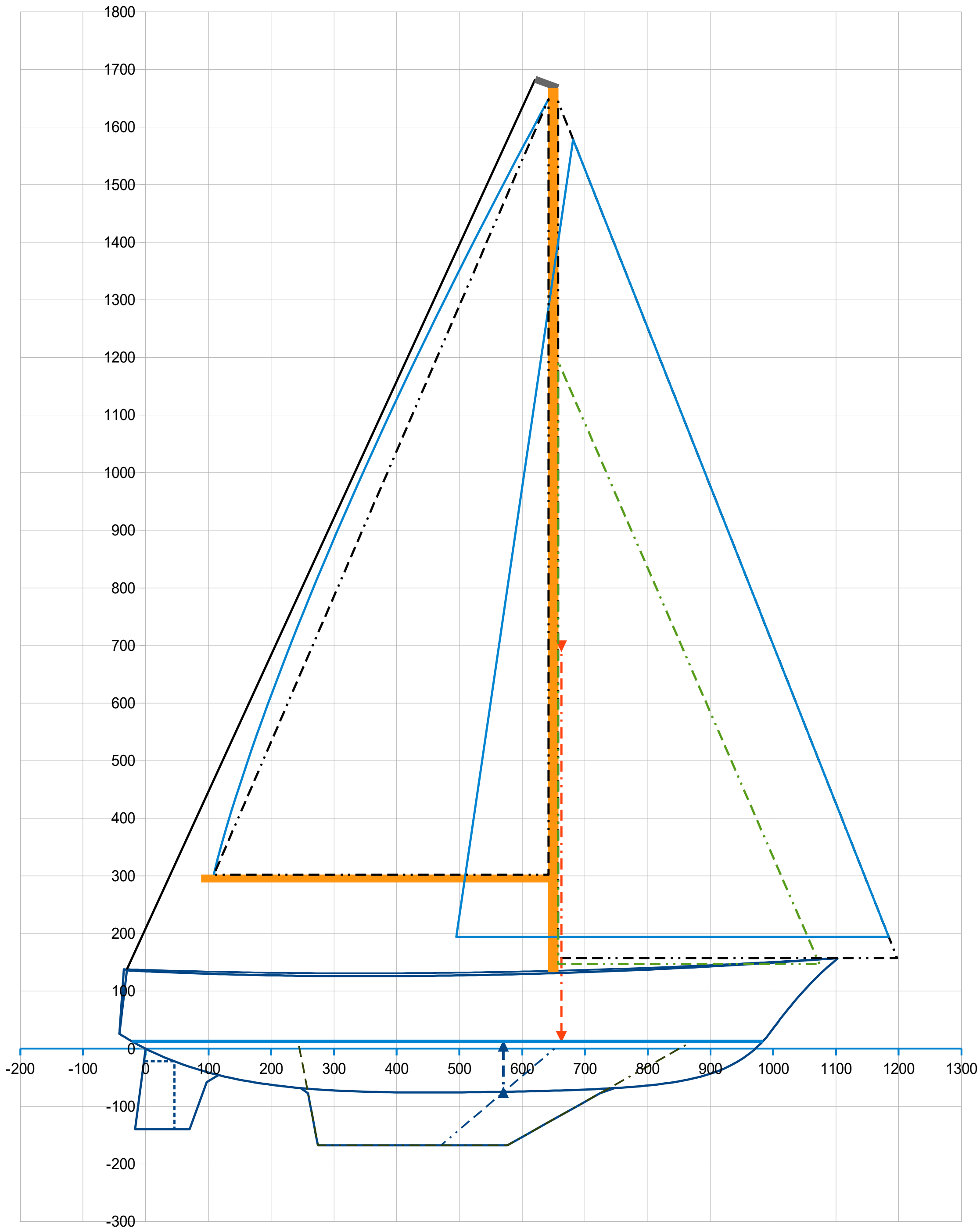
Data to enter		>> in feet
Xmast (m)	**6,49500**	*21,31*
Zboom(m)	**2,95700**	*9,70*
I (m)	**15,08760**	*49,50*
J (m)	**5,40414**	*17,73*
P (m)	**13,46200**	*44,17*
E (m)	**5,33400**	*17,50*
Iy (m)	**10,57910**	*34,71*
Jy (m)	**4,16560**	*13,67*

Output considering the sail triangles, used for the CE (Center of Effort) involved in the Lead assessment

Fore triangle (m2)	40,8			
Inner staysail triangle (m2)	22,0			
Main triangle (m2)	35,9			
Mizzen triangle (m2)	0,0			
Sloop triangles St (m2)	**76,7**	*825,28*	*sqft*	
XCE (m)	6,63	ZCE (m)	6,99	
Lead (CE – CLR) (% Lwl)	**9,2**	**5 to 9 recommended for fin-keel yacht with masthead rig**		

CLR method : keel profile extended to the waterline for 14000 kg, CLR at 35% chord and 45% draft oa

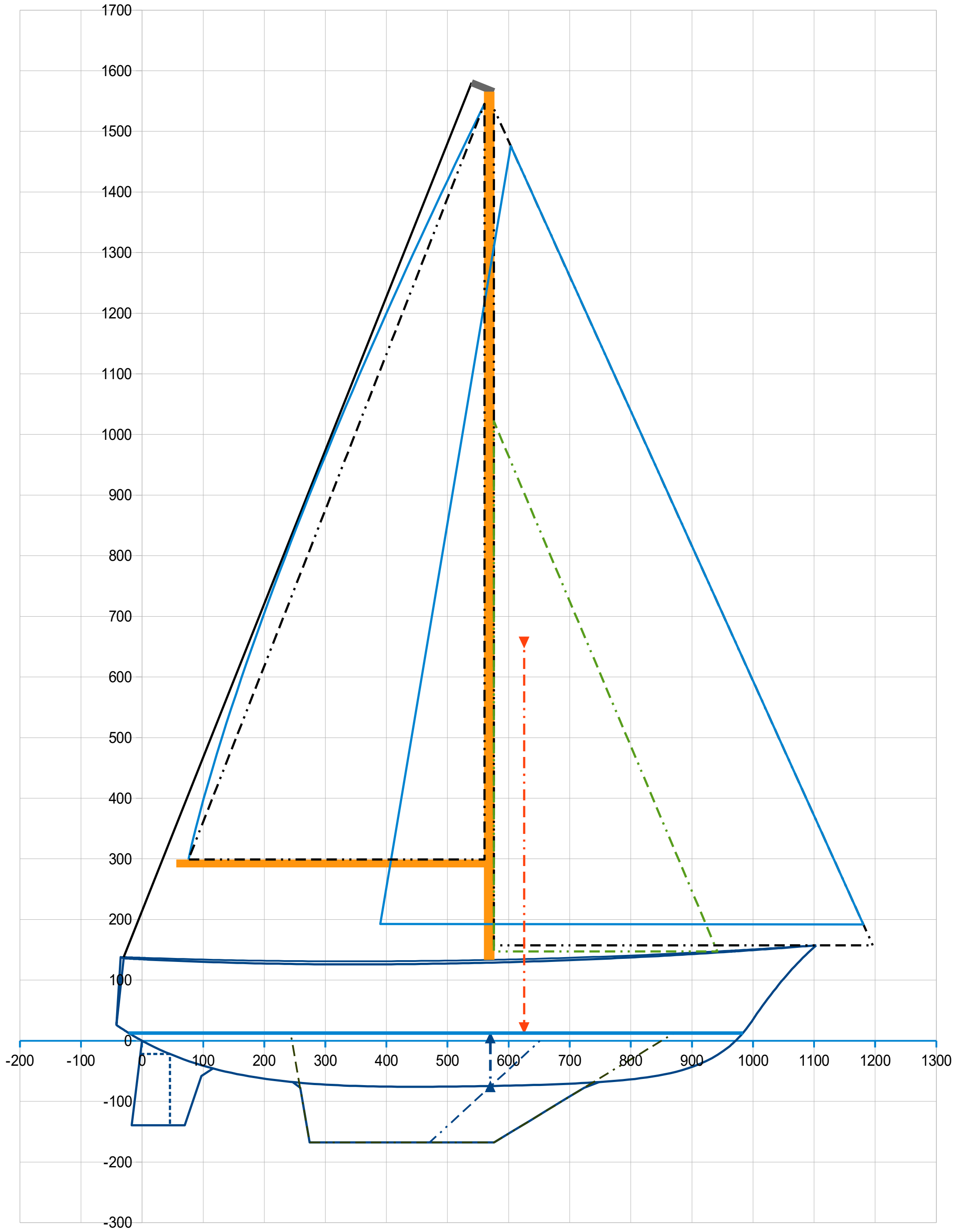
CE method : geometrical center of the 2 triangles + (if any) mizzen triangle at 50%



mk1 cutter 46' bow-sprit >> Lead 5,5 % Lwl (Rake 0°) to 4,3 % (Rake 1,3°) **/ 5 to 9 recommended**

Data to enter							
Xmast (m)	**5,682**	**Output considering the sail triangles, used for the CE (Center of Effort) involved in the Lead assessment**					
Zboom(m)	**2,926**	Fore triangle (m2)	43,5				
I (m)	**14,021**	Inner staysail triangle (m2)	16,2				
J (m)	**6,202**	Main triangle (m2)	30,2				
P (m)	**12,466**	Mizzen triangle (m2)	0,0				
E (m)	**4,846**	**Sloop triangles St (m2)**	**73,7**	*793,17*	*sqft*		
Iy (m)	**8,865**	XCE (m)	6,25	ZCE (m)	6,57		
Jy (m)	**3,658**	**Lead (CE – CLR) (% Lwl)**	**5,5**	**5 to 9 recommended for fin-keel yacht with masthead rig**			

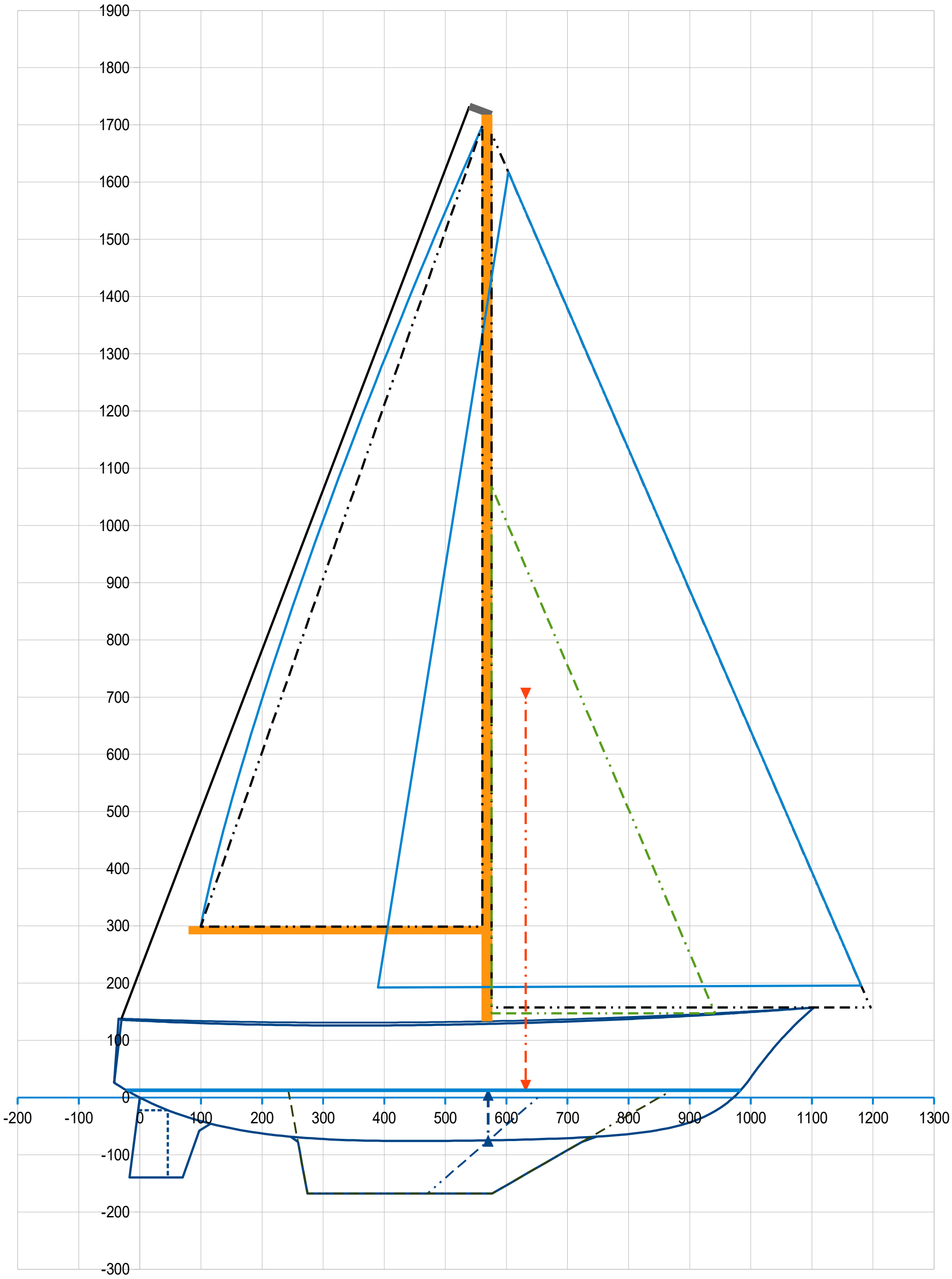
CLR method : keel profile extended to the waterline for 14000 kg, CLR at 35% chord and 45% draft oa
CE method : geometrical center of the 2 triangles + (if any) mizzen triangle at 50%



mk1 cutter 51' bow-sprit >> Lead 6,1 % Lwl (Rake 0°) to 4,8 % (Rake 1,3°) **/ 5 to 9 recommended**

Sailplan – early stage definition								
Data to enter		*>> in feet*	**Output considering the sail triangles, used for the CE (Center of Effort) involved in the Lead assessment**					
Xmast (m)	**5,68198**	*18,64*	Fore triangle (m2)	48,0				
Zboom(m)	**2,92608**	*9,60*	Inner staysail triangle (m2)	17,0				
I (m)	**15,49400**	*50,83*	Main triangle (m2)	32,2				
J (m)	**6,20217**	*20,35*	Mizzen triangle (m2)	0,0				
P (m)	**13,99032**	*45,90*	**Sloop triangles St (m2)**	**80,3**	*864,31*	*sqft*		
E (m)	**4,61010**	*15,13*	XCE (m)	6,32	ZCE (m)		7,06	
Iy (m)	**9,32180**	*30,58*	**Lead (CE – CLR) (% Lwl)**	**6,1**	**5 to 9 recommended for fin-keel yacht with masthead rig**			
Jy (m)	**3,65760**	*12,00*						

CLR method : keel profile extended to the waterline for 14000 kg, CLR at 35% chord and 45% draft oa
CE method : geometrical center of the 2 triangles + (if any) mizzen triangle at 50%



mk1 cutter 51' tallmast, boom shortened by 36'' :

Rake 0° : Lead 2,9 % Lwl >> 5,9 % / 5 to 9 recommended

Rake 1,3° : Lead 1,6 % >> 4,6 %

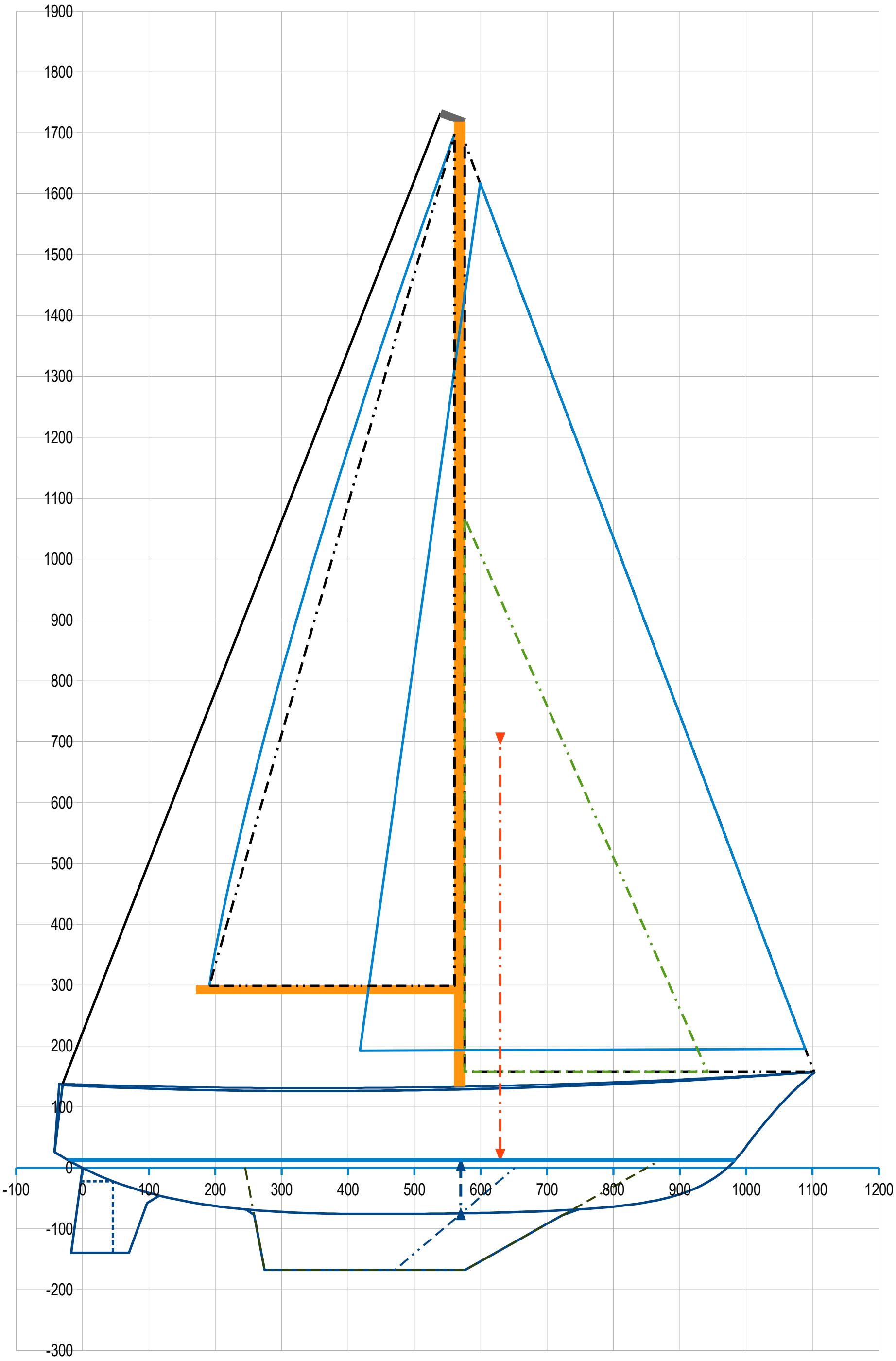
Data to enter	
Xmast (m)	5,682
Zboom(m)	2,926
I (m)	15,494
J (m)	5,263
P (m)	13,990
E (m)	3,696
Iy (m)	9,322
Jy (m)	3,658

Output considering the sail triangles, used for the CE (Center of Effort) involved in the Lead assessment

Fore triangle (m2)	40,8			
Inner staysail triangle (m2)	17,0			
Main triangle (m2)	25,9			
Mizzen triangle (m2)	0,0			
Sloop triangles St (m2)	**66,6**	*717,15*	*sqft*	
XCE (m)	6,29	ZCE (m)	7,05	
Lead (CE – CLR) (% Lwl)	**5,9**	**5 to 9 recommended for fin-keel yacht with masthead rig**		

CLR method : keel profile extended to the waterline for 14000 kg, CLR at 35% chord and 45% draft oa

CE method : geometrical center of the 2 triangles + (if any) mizzen triangle at 50%



mk1 cutter 46' shortmast >> bow-sprit 36'' , bow end tack used for the inner staysail :

Rake 0° : Lead 2,3 % Lwl >> 5,5 % / 5 to 9 recommended

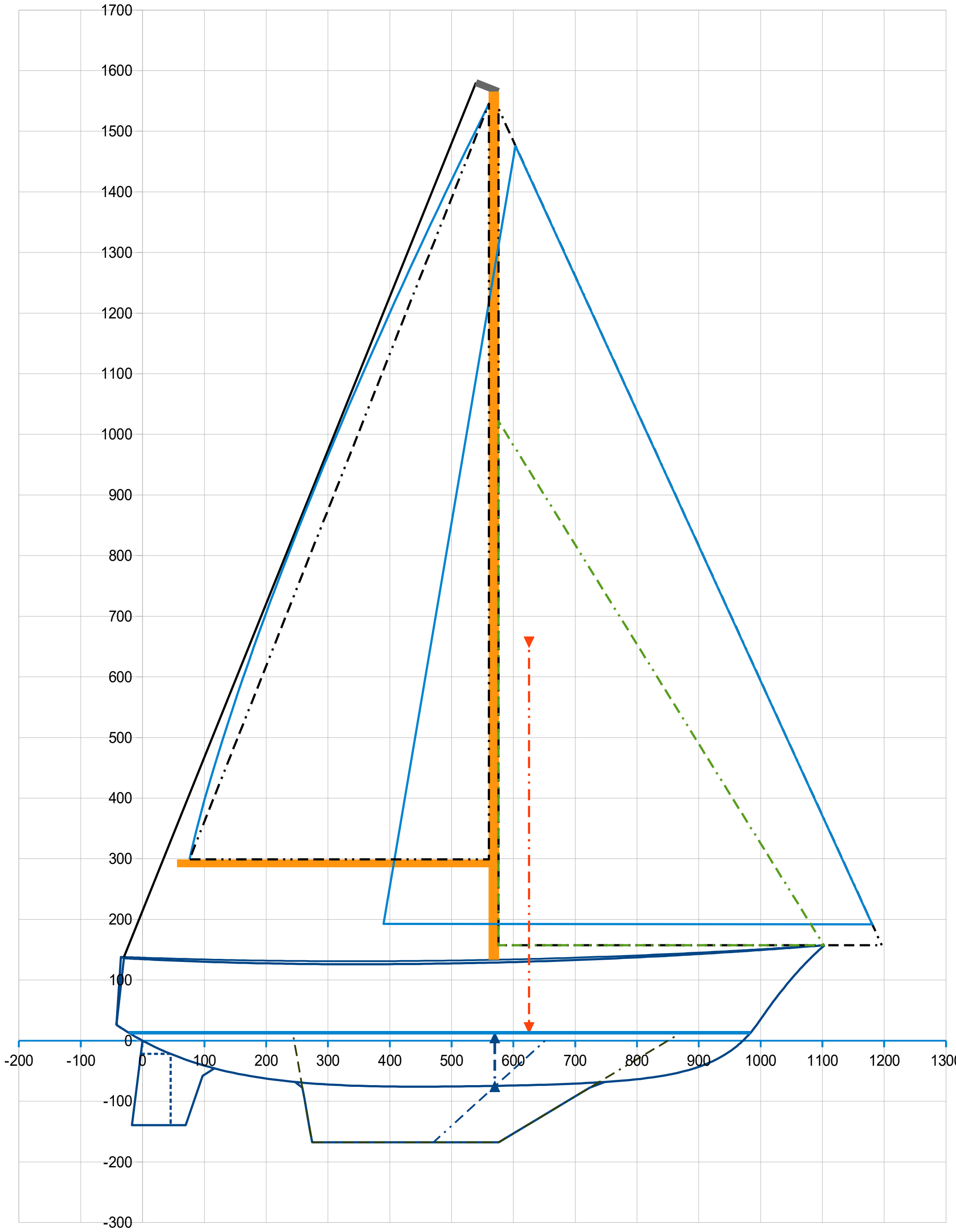
Rake 1,3° : Lead 1,1 % >> 4,3 %

Data to enter						
Xmast (m)	**5,682**	**Output considering the sail triangles, used for the CE (Center of Effort) involved in the Lead assessment**				
Zboom(m)	**2,926**	Fore triangle (m2)	43,5			
I (m)	**14,021**	Inner staysail triangle (m2)	23,3			
J (m)	**6,202**	Main triangle (m2)	30,2			
P (m)	**12,466**	Mizzen triangle (m2)	0,0			
E (m)	**4,846**	**Sloop triangles St (m2)**	**73,7**	*793,17*	*sqft*	
Iy (m)	**8,865**	XCE (m)	6,25	ZCE (m)		6,57
Jy (m)	**5,263**	**Lead (CE – CLR) (% Lwl)**	**5,5**	**5 to 9 recommended for fin-keel yacht with masthead rig**		

CLR method : keel profile extended to the waterline for 14000 kg, CLR at 35% chord and 45% draft oa

CE method : geometrical center of the 2 triangles + (if any) mizzen triangle at 50%

Question : is there a need to re cut the (lower edge of) inner staysail ?



mk1 cutter 46' tallmast >> bow-sprit 36'' , bow end tack used for the inner staysail :

Rake 0° : Lead 2,9 % Lwl >> 6,1 % / 5 to 9 recommended

Rake 1,3° : Lead 1,6 % >> 4,8 %

Data to enter		Output considering the sail triangles, used for the CE (Center of Effort) involved in the Lead assessment				
Xmast (m)	**5,682**					
Zboom(m)	**2,926**	Fore triangle (m2)	48,0			
I (m)	**15,494**	Inner staysail triangle (m2)	24,5			
J (m)	**6,202**	Main triangle (m2)	32,2			
P (m)	**13,990**	Mizzen triangle (m2)	0,0			
E (m)	**4,610**	**Sloop triangles St (m2)**	**80,3**	*864,31*	*sqft*	
Iy (m)	**9,322**	XCE (m)	6,32	ZCE (m)	7,06	
Jy (m)	**5,263**	**Lead (CE – CLR) (% Lwl)**	**6,1**	**5 to 9 recommended for fin-keel yacht with masthead rig**		

CLR method : keel profile extended to the waterline for 14000 kg, CLR at 35% chord and 45% draft oa

CE method : geometrical center of the 2 triangles + (if any) mizzen triangle at 50%

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