Volvo Ocean Race Inshore Foiler

39’ Foiler

Executive Summary

This document serves introduces and describes a VOR racing foiler offered in response to the Volvo Ocean Race's Notice of Tender, dated May 2017. The design is targeted specifically a the In-Port Series of races during the Volvo Ocean Race.

It will race with 5 people on board, 4 crew and 1 VIP guest.

The following briefly summarizes without detail how the project matches the request. More detail is offered later in this document.

- **Cost**

Project budget is 730,000 Euro per team. Throughout the preliminary design phase, cost reductions have been utilized, while providing a high performing race boat.

- **Ease of operation**

The foiler is designed to be assembled and disassembled quickly, being stored in a shipping container. Design choices limit damage and expense in the event of capsize and collision. It will anchor normally from the bow, and crew may move easily from a RIB or dock to the cockpit.

- **Ease of use**

The most notable feature in the use of the boat is that the crew remains in a cockpit, not changing sides. There are just two sails and relatively few sail controls, led to two winches. Foil control, in the hands of two crew, will be augmented by electronics. Power for electric actuation systems will come from an onboard battery.

Executive Summary

- **Sustainability**

Both recycled and recyclable materials is considered for both boat and tooling. Currently, bio composites account for about 20% of structural and fairing weight. Shoreside renewable energy is the source for onboard electrical power.

- **Safety**

Many features of the design add to the increased level of safety. The foil layout nearly prohibits bow down pitch due to main foil ventilation. The crew sits in the center, forward of the mast, in a covered safety cell. Escape hatches are provided for the cockpit, in the event of capsize.

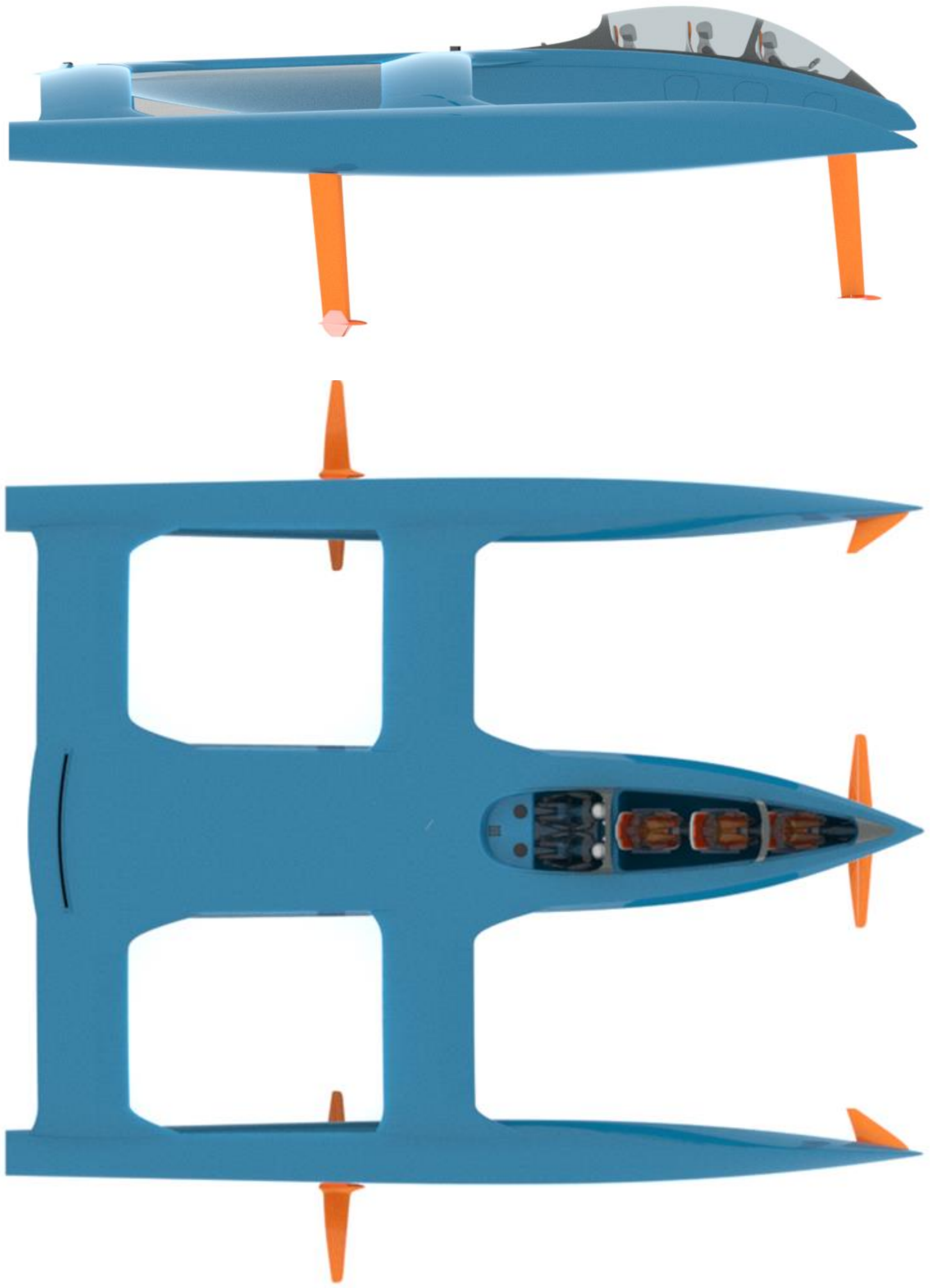
- **Look**

The style and function of the boat is unlike racing cats to date. In appearance, it draws as much on unlimited hydroplane or combat aircraft as from current boats. This serves the parallel goals of low windage and safety concerns. It also corresponds well with the primary sponsors long time reputation for being the safest in the business. As a racing yacht, the design highlights concentration, race management and foiling skill.

- **Completeness**

This foiler is provided as a complete design/build package including Schickler Tagliapietra together with DNA Performance Sailing and/or Enata Industries. It will be supported by external professionals with experience at the highest levels of racing yacht design.

The Design



Principal Dimensions

LOA	11.8 m
BOA	9.0 m
Draft	2.4 m
Air draft	18.2 m
LS weight	1400 kg
Sailing weight	1800 kg
Crew	4
Guest	1
RM (static)	7.6 tm
RM (dynamic)	~15 tm

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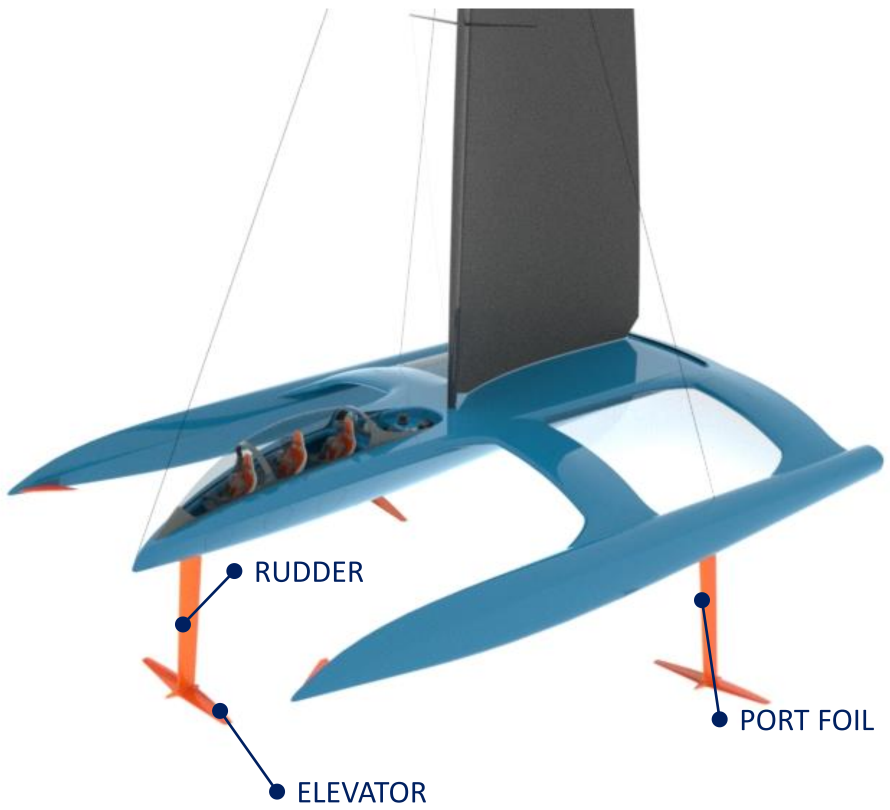
The Design

The boat is a catamaran with a significantly large nacelle on centerline. This is raised above the water at rest. The vessel is intended to operate 99% of the time in foiling mode, already with 6 knots of wind (downwind). The foil arrangement is novel, with two primary foils aft and a forward centerline rudder and stabilizer. This layout is analogous to a canard type aircraft.

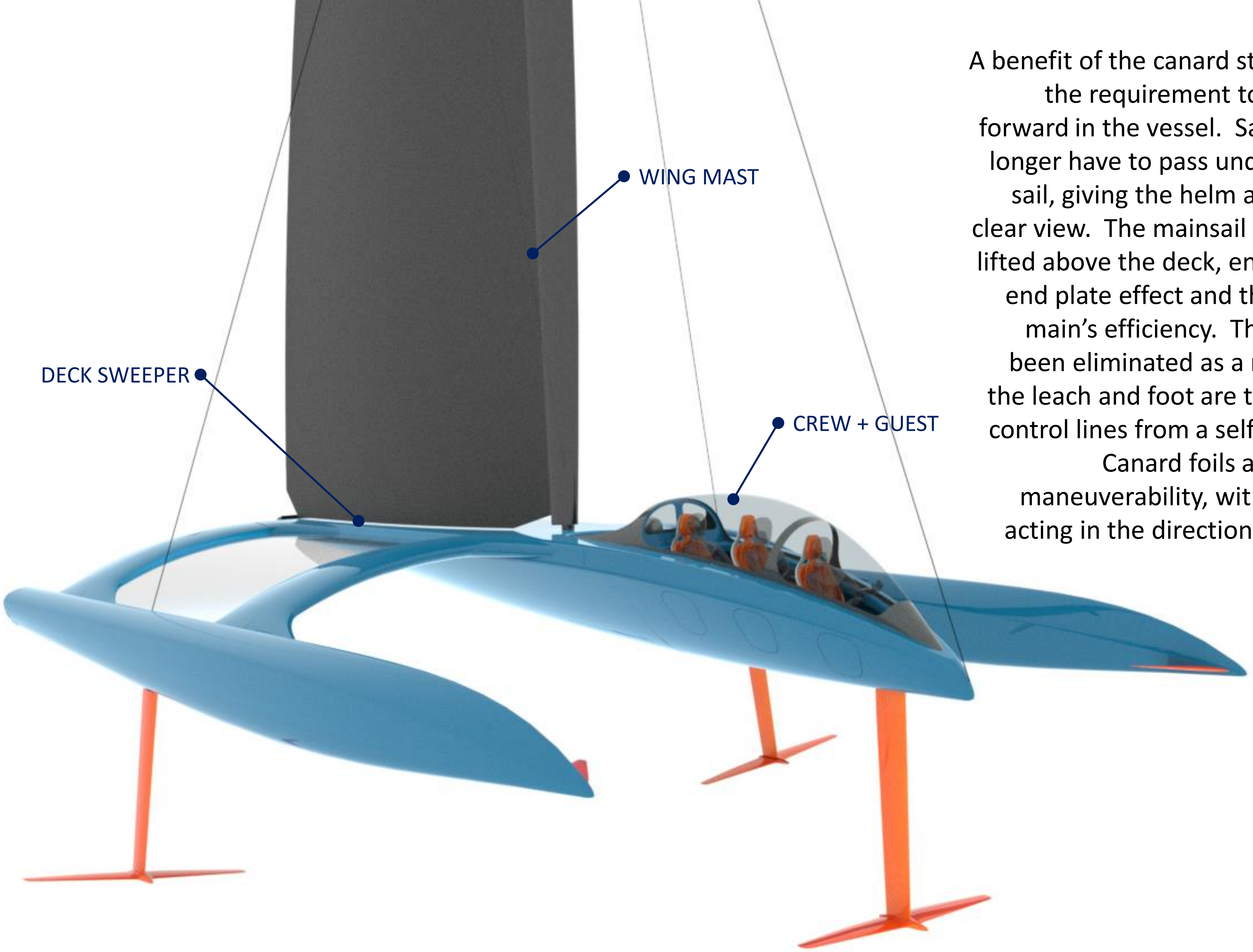
When the vessel is sailed, the crew will not move from side to side. They will remain in the forward nacelle cockpit and operate the boat from there. Stability or righting moment will be provided by hydrodynamic forces, not by movement of weight. This means that the primary lifting foils will have differential lift.

Fairings are intended to be very light weight and fully re-usable. The primary material for the fairings is to be bamboo fibre laminate plies set in bio resin.



The Design

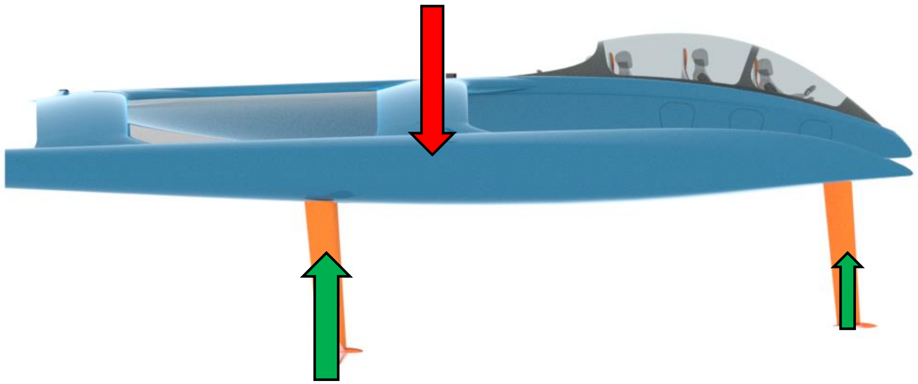
Although the layout is innovative, the elements have been proven in practice. It begins with flapped foils, long proven in the moth to work for automatic ride height control. The big advantages of the flapped foil are reduced control forces, and with that lower costs, as well as good hydrodynamic behavior. The concept of differential lift has been proven in the most recent Americas Cup in the rudder setup. As a primary source of righting moment, it has been long proven by the trifoiler design, as has the central unmoving position of the crew.

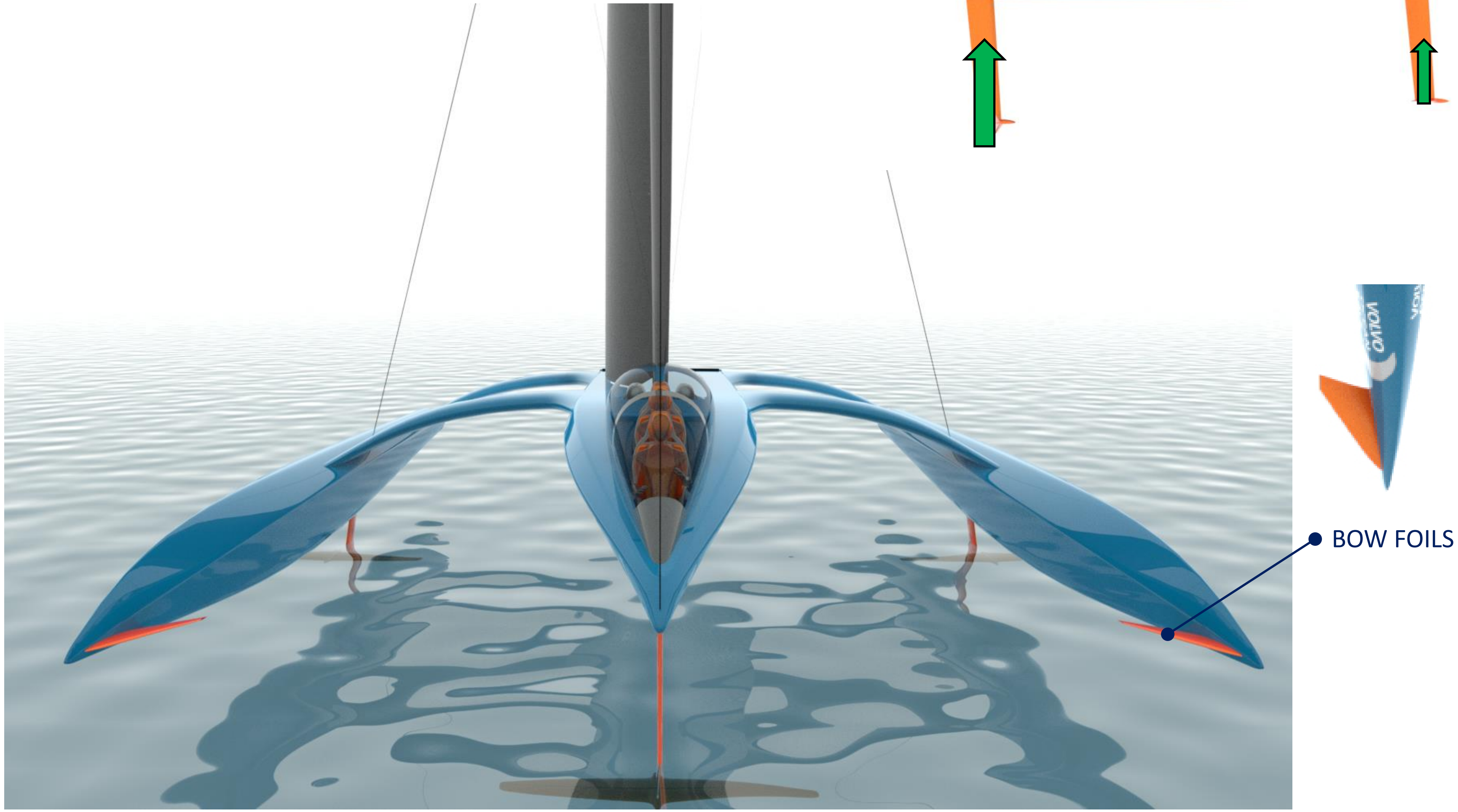


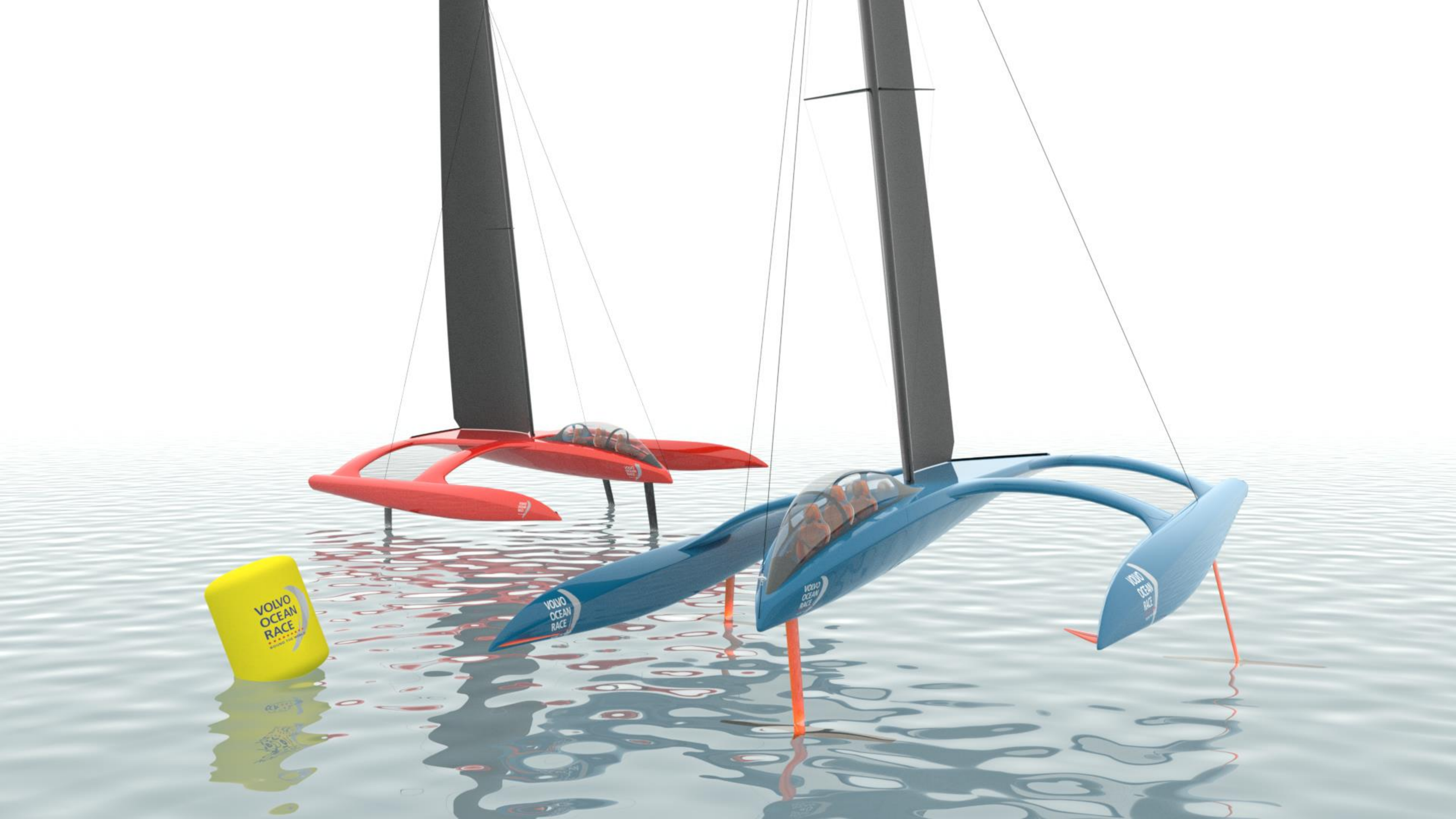
A benefit of the canard style layout is the requirement to put weight forward in the vessel. Sailors will no longer have to pass under the main sail, giving the helm a 270 degree clear view. The mainsail need not be lifted above the deck, enhancing the end plate effect and therefore the main's efficiency. The boom has been eliminated as a result, while the leach and foot are tensioned by control lines from a self-tacking car. Canard foils also enhance maneuverability, with each force acting in the direction of intended movement.

The Design

Foiling catamarans are known to have big nose dives, caused by ventilation of the main foil, very demanding on crew and equipment. In the canard layout, the boat is much less sensitive to nose dives. If the main foil would ventilate, the stern of the vessel will go down, unlike conventional foil layouts. The knock-on effect of this behavior is the possibility to reduce bow volumes and high bows. As a precaution, a pivoting foil has been fitted to each bow, taking advantage of the speed involved. The pivot is placed well aft, to create a large restoring hydrodynamic force if the bow enters the water.



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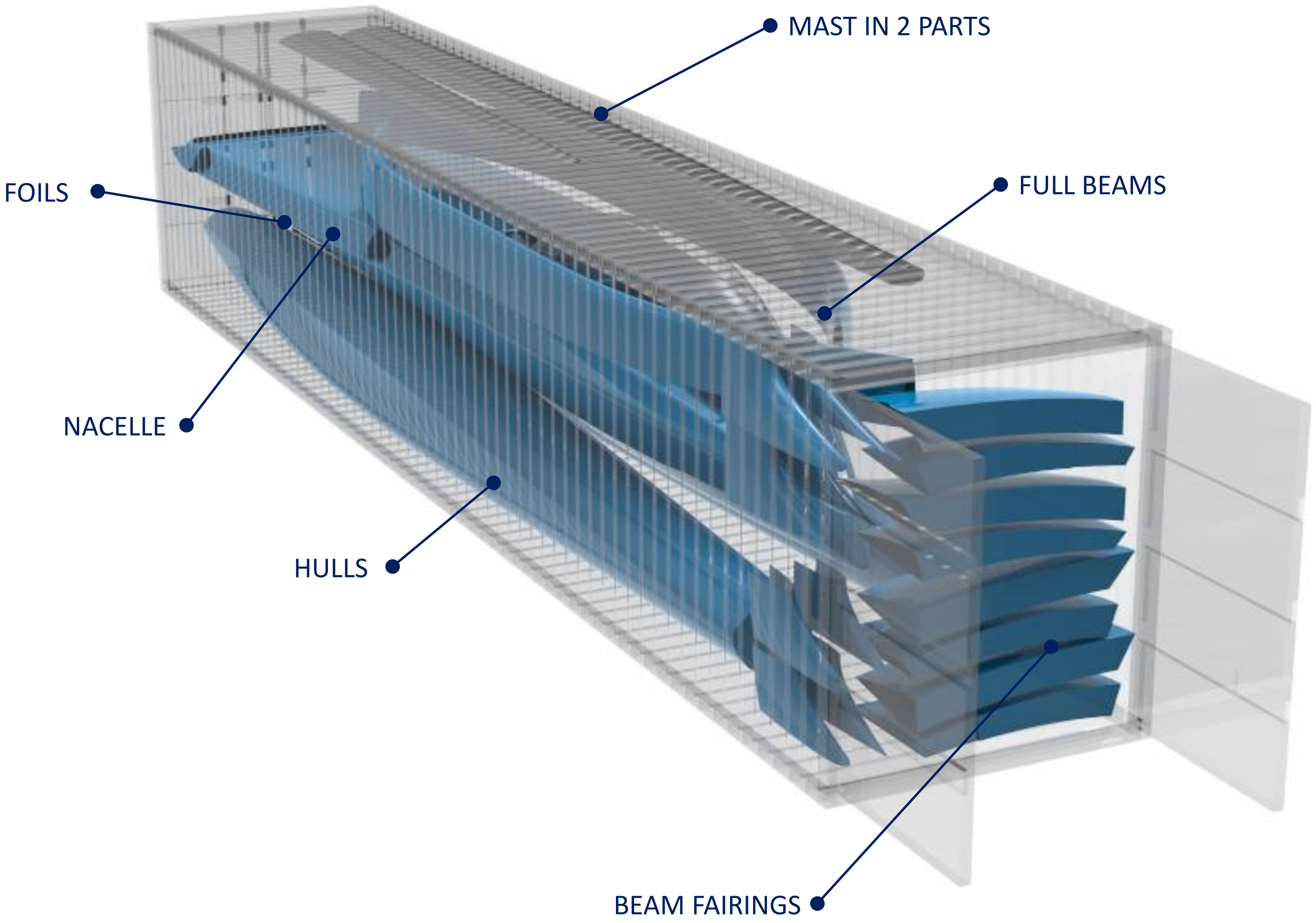
Transport and Storage

The foiler is designed to be assembled and disassembled quickly, being stored in one shipping container. The fairings on the aft edges are divided in two pieces and the beam end fairings are removed. The mast is likewise split in two pieces at the diamond strut. Although it is possible to separate the forward and aft end of the main hulls, this is for ease of repair rather than transport. The nacelle contains virtually all of the systems, making setup less demanding.



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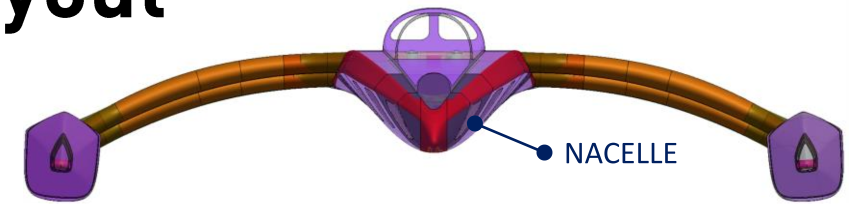
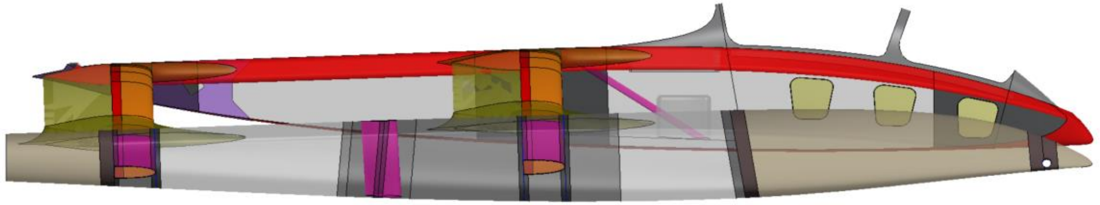
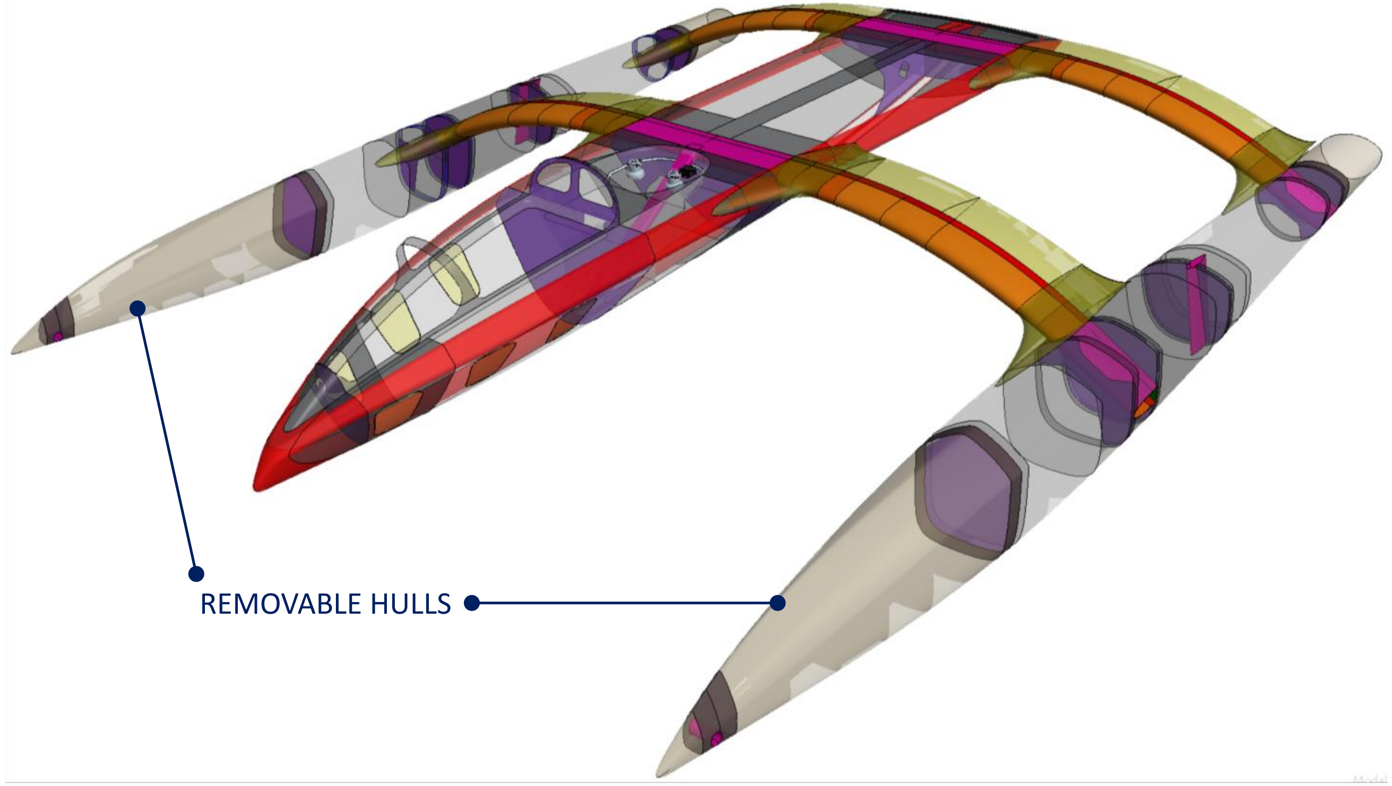
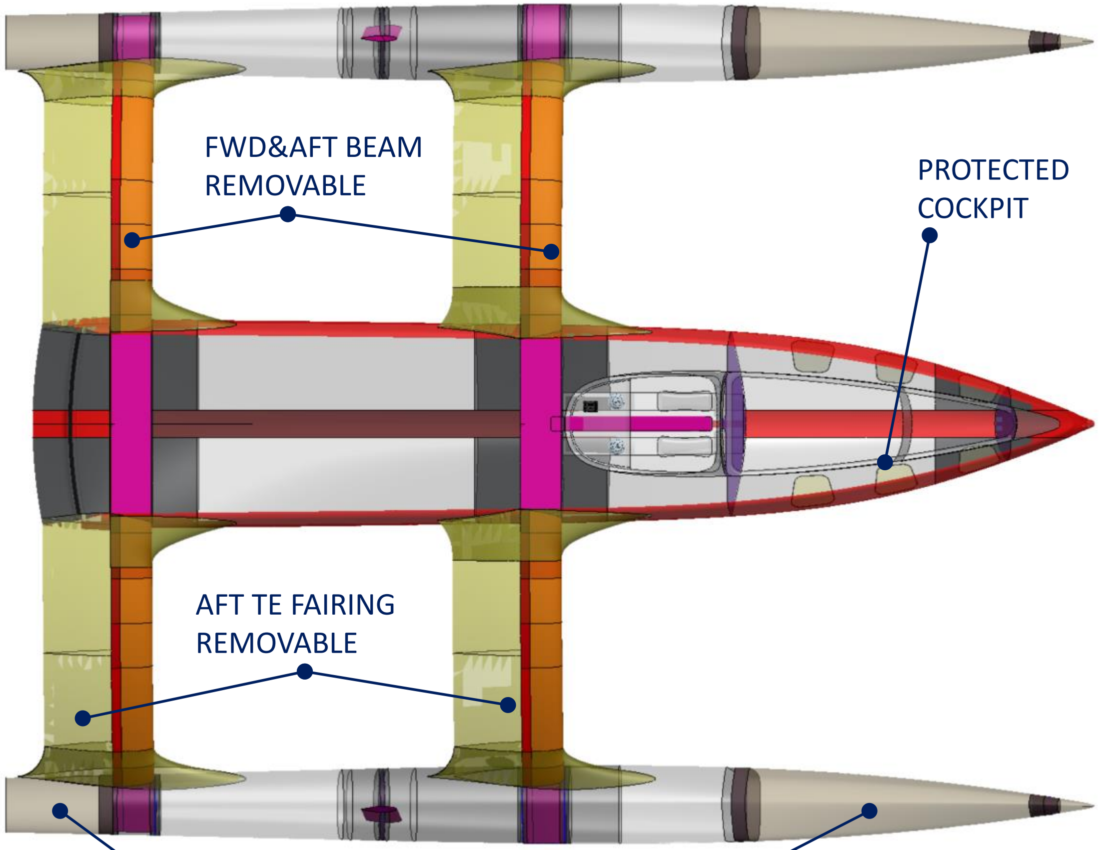
Structural Layout

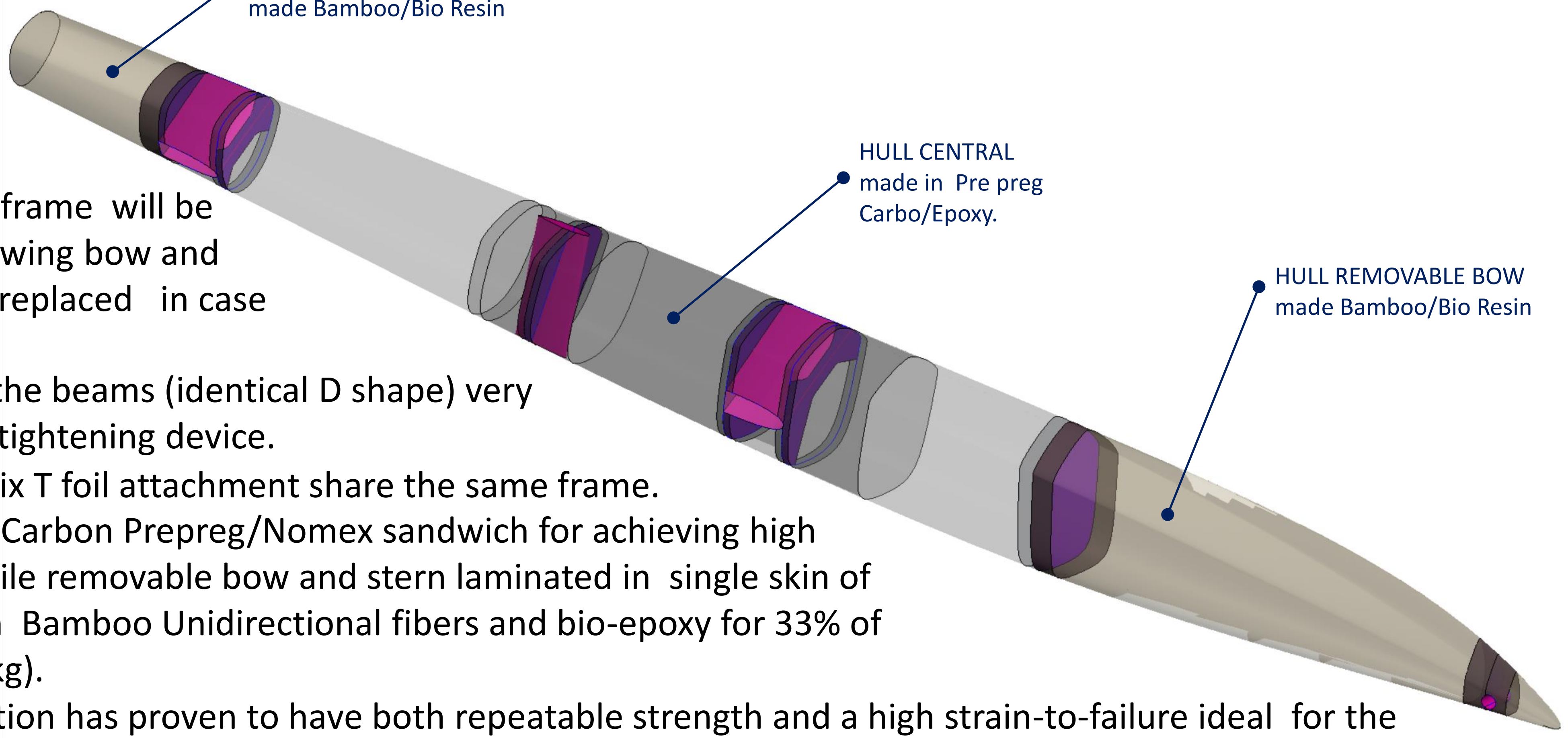








Hulls

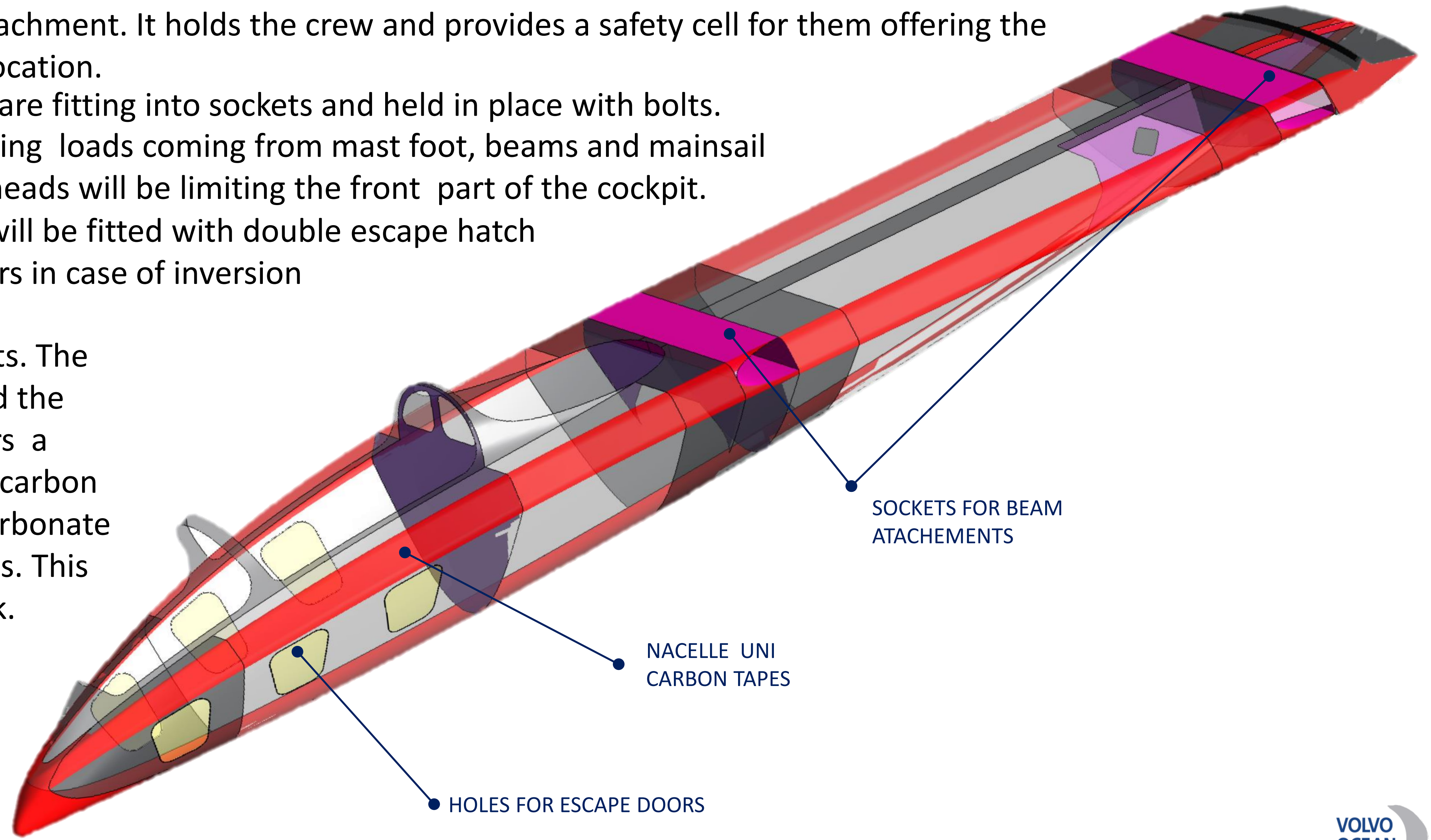


Each hull will be fitted with 6 frames.
The forward and the aft frame will be watertight bulkheads allowing bow and stern to be removed and replaced in case of damage.
Sockets layout for fitting the beams (identical D shape) very quickly with a single bolt tightening device.
Shrouds chain plate and fix T foil attachment share the same frame.
Central hull part made in Carbon Prepreg/Nomex sandwich for achieving high stiffness/weight ratio, while removable bow and stern laminated in single skin of Bio-composite made with Bamboo Unidirectional fibers and bio-epoxy for 33% of the total hull weight (97 kg).
Bamboo/Epoxy combination has proven to have both repeatable strength and a high strain-to-failure ideal for the main purpose of both the hull ends. The ECO-cost of the composite due to the natural fiber low carbon foot print and the low amount of resin required is guaranteeing a credit until the dismantling when combustion may released the CO2 initially stored

Nacelle

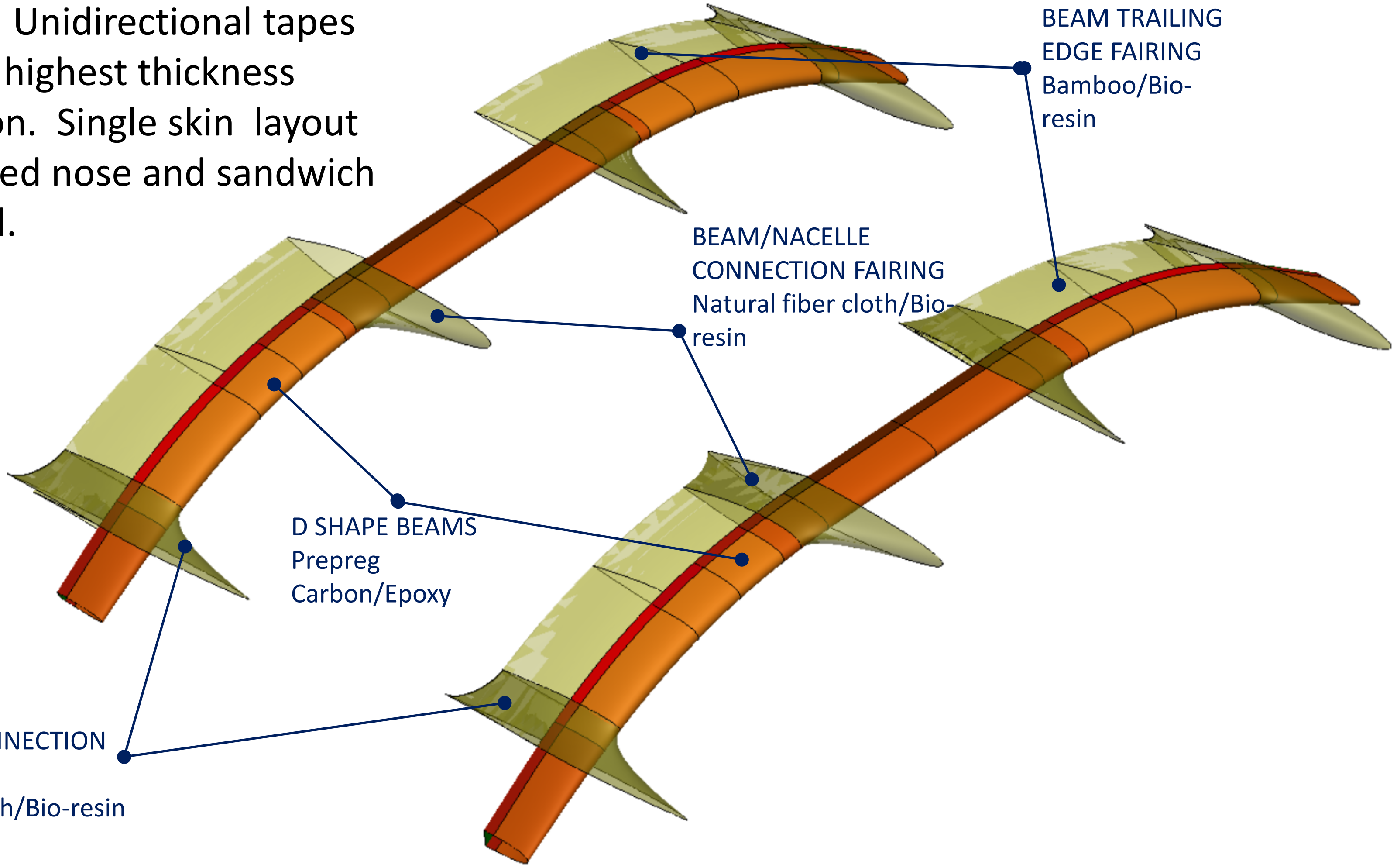
The nacelle serves as primary spine structural element sharing big portion of the load from the rig and supporting front rudder attachment. It holds the crew and provides a safety cell for them offering the front part as ideal canopy location.
The two transverse beams are fitting into sockets and held in place with bolts.
Four frames will be supporting loads coming from mast foot, beams and mainsail leech. Two watertight bulkheads will be limiting the front part of the cockpit.
Holes on the nacelle sides will be fitted with double escape hatch for each front crew members in case of inversion

The cockpit will be two parts. The front will be water tight and the after will allow the trimmers a quick access to the deck. A carbon fibre frame will hold polycarbonate or similar moulded windows. This Canopy will seal to the deck.



Beams & Fairings

Beam having D shape will be done in Carbon Prepreg laminated in a female mould. Unidirectional tapes will run at the highest thickness section position. Single skin layout for the U shaped nose and sandwich for the vertical.



Much of the visible surface will be lightweight fairings, owing to the lack of crew movement and the high speed of the vessel. Single skin Bamboo/Bio-resin made by unidirectional thin laminated plies will be used for the trailing edges fairing while natural fibers cloth/Bio-resin will be adopted for the more complicated shapes of beam/hull/nacelle connection fairings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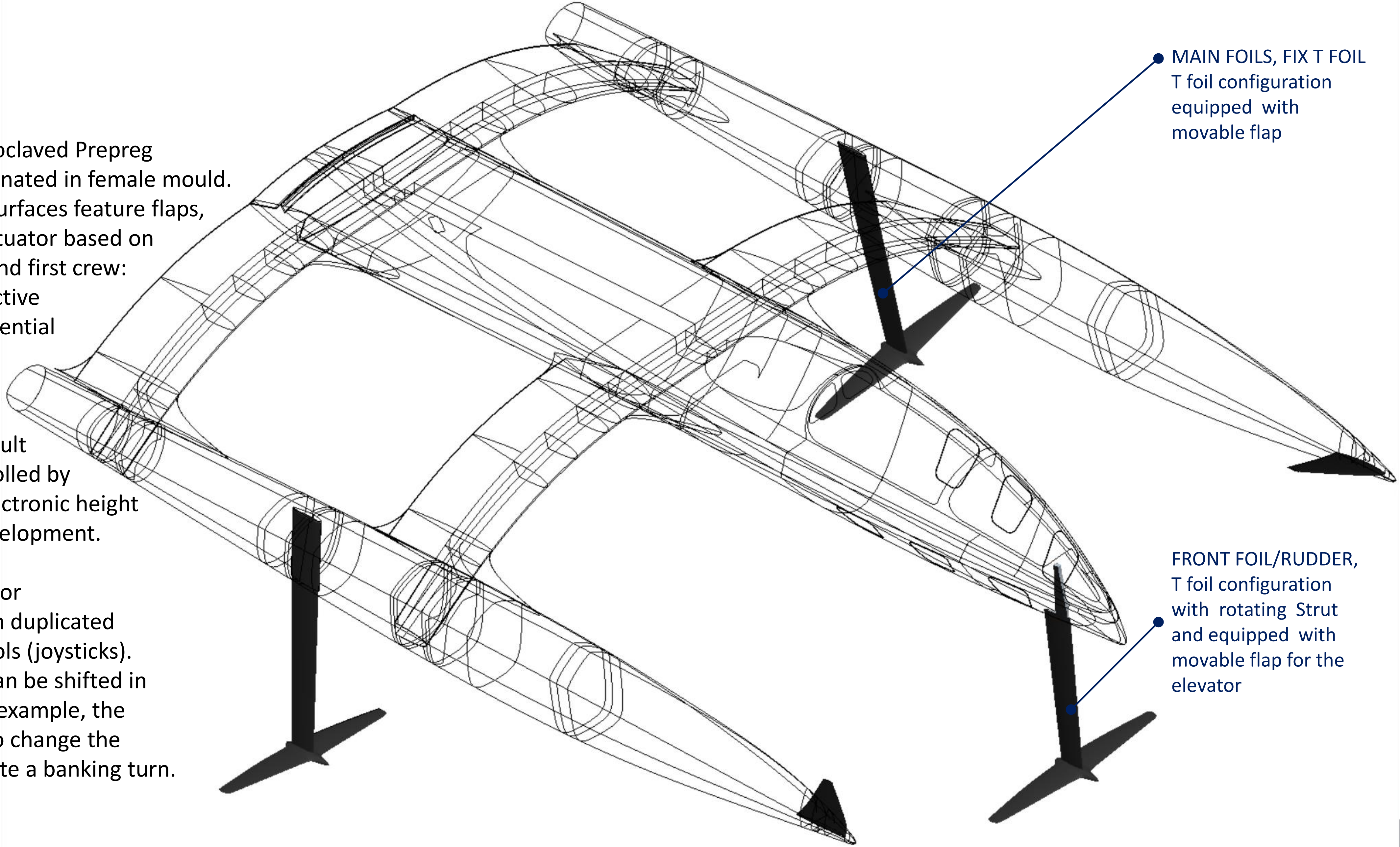
Foils

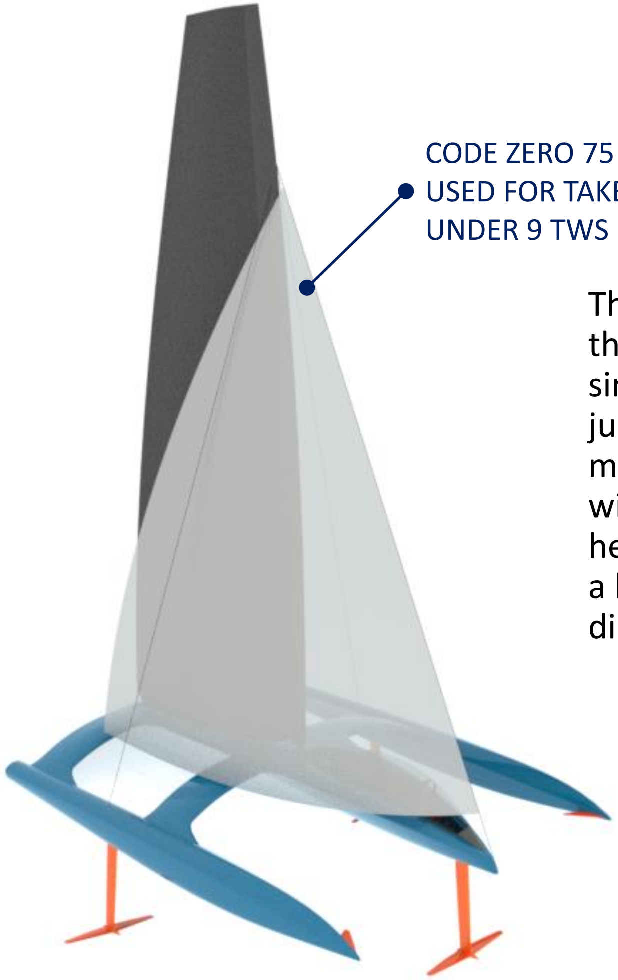
Foil will be done in autoclaved Prepreg
Carbon/Epoxy and laminated in female mould.
All 3 horizontal lifting surfaces feature flaps,
Moved with a linear actuator based on
Inputs from the helm and first crew:
Main flap angle – collective
Main flap angle – differential
Elevator flap angle
Rudder angle

Ride height will by default
be automatically controlled by
computer, based on electronic height
sensor, a recent AC development.

The vessel is intended for
Fly-by-wire control with duplicated
Human Interface controls (joysticks).
Priority over controls can be shifted in
Maneuvers, giving, for example, the
helmsman the ability to change the
differential lift to execute a banking turn.



Sailplan, Mast and Rigging



The wing mast is able to rotate on its own axis, with the aid of an inducer. It is rigged with diamonds, single shrouds and a headstay, while being fitted for just two sails, including a reefable deck sweeping main. In almost all circumstances the vessel will sail with only the main sail. In very light winds a furling headsail may be set. Design intent is avoid the use of a boom, instead bringing both foot and leach tension directly into the nacelle.

I	13.5 m
P	16.8 m
E	5.0 m
HB	1.8 m
Mast	10 m^2
Main	64 m^2
Code 0	75 m^2

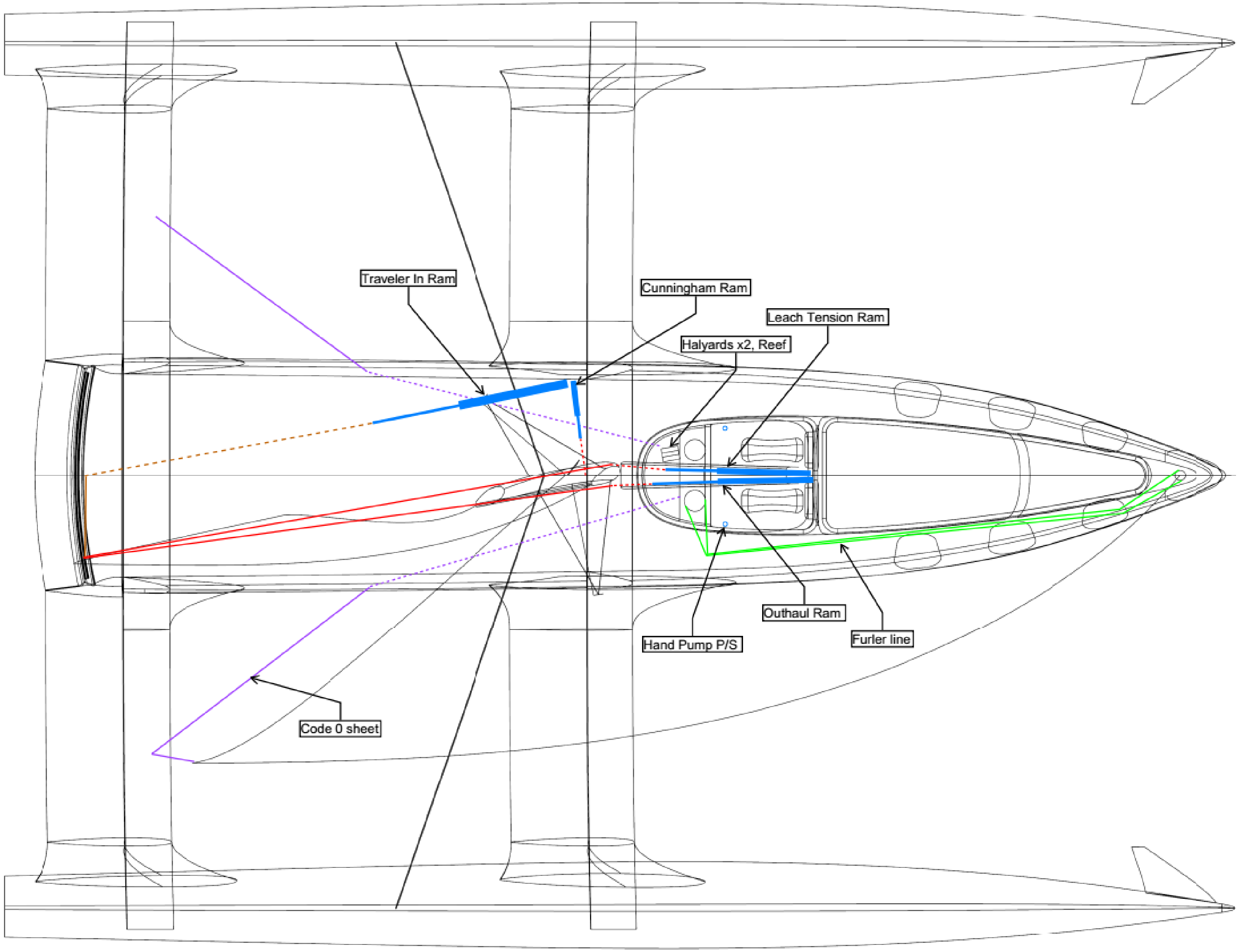
Deck Layout

There will be a minimum of sail controls. The angle of attack of the main will be by means of a 1:1 main traveler line led to a hydraulic ram. A pair of rams will independently apply leach tension and foot tension. Luff tension will be by a hydraulic cunningham.

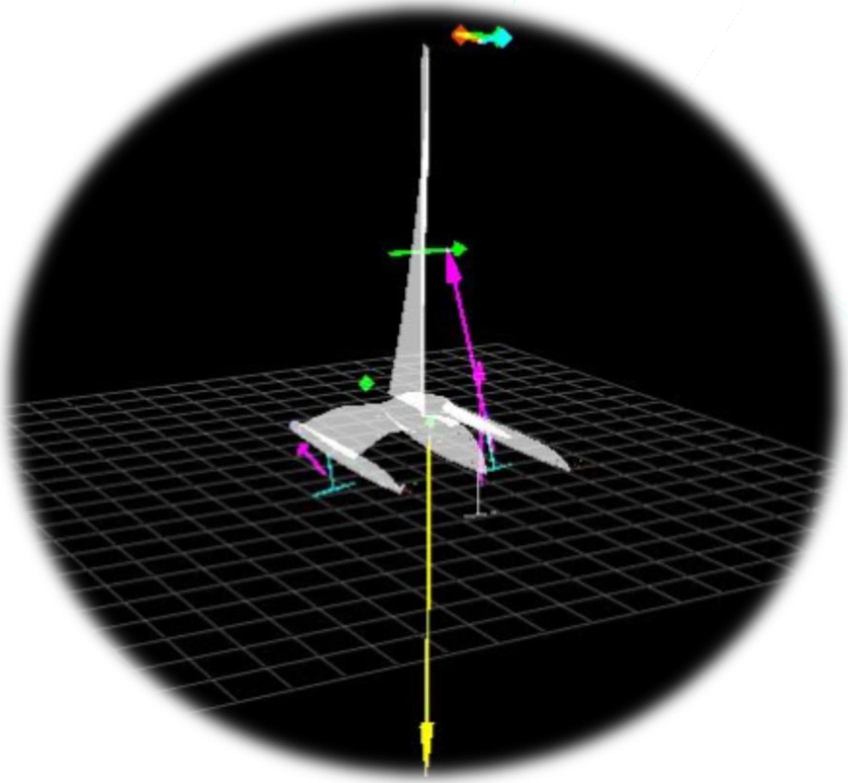
The vessel will require pre-rigged “single line” reefing to be operated from the cockpit. Once the reef is in place, a crew may need to reset the attachment of strops and use a zip to contain the sail cloth.

The points of sheeting the code 0 will be fixed. A manual continuous line furler is anticipated. All deck controls will lead to the aft end of the cockpit for the sail trimmers, who will provide the necessary hydraulic power with hand pumps.

Two electric winches are used for halyards, reef lines and code 0 sheets.

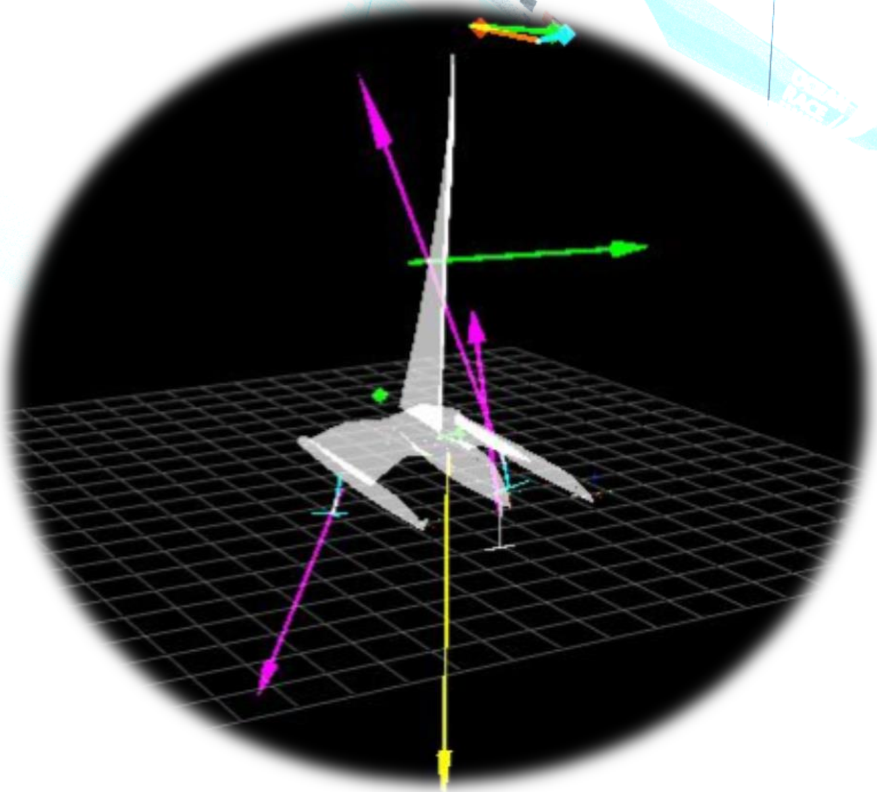


Performance



Upwind 8 TWS, foiling at 10.5 knots
AWA 19.3, Nearly neutral windward foil

Upwind 15 TWS, foiling at 25 knots
AWA 18.4, Dynamic stability at 65% max allowable



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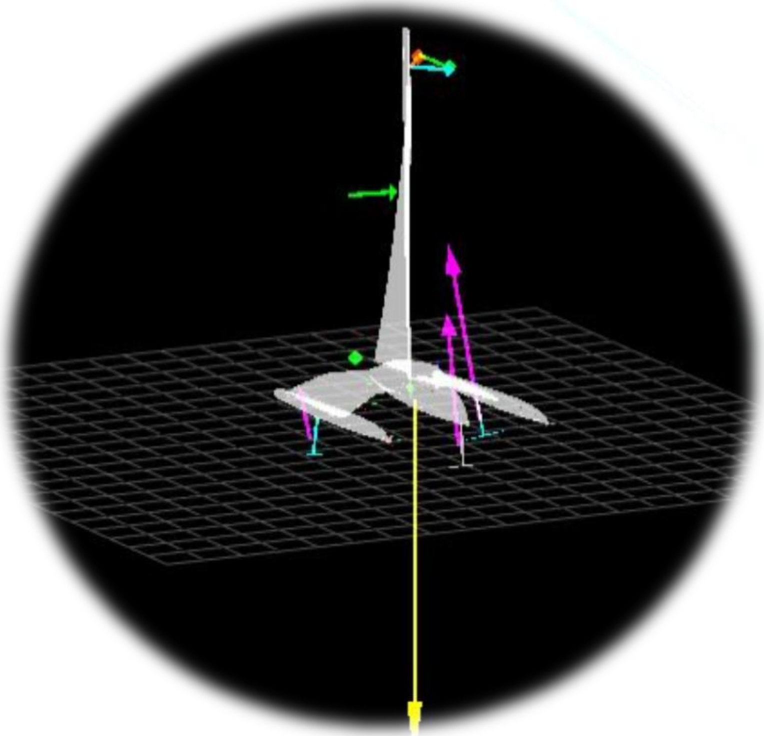
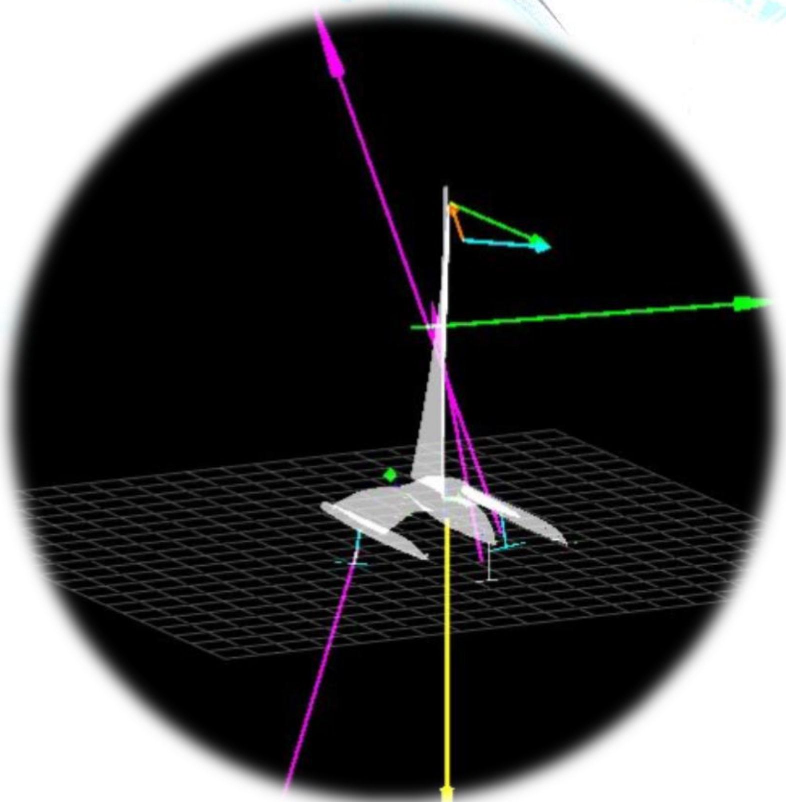
Performance



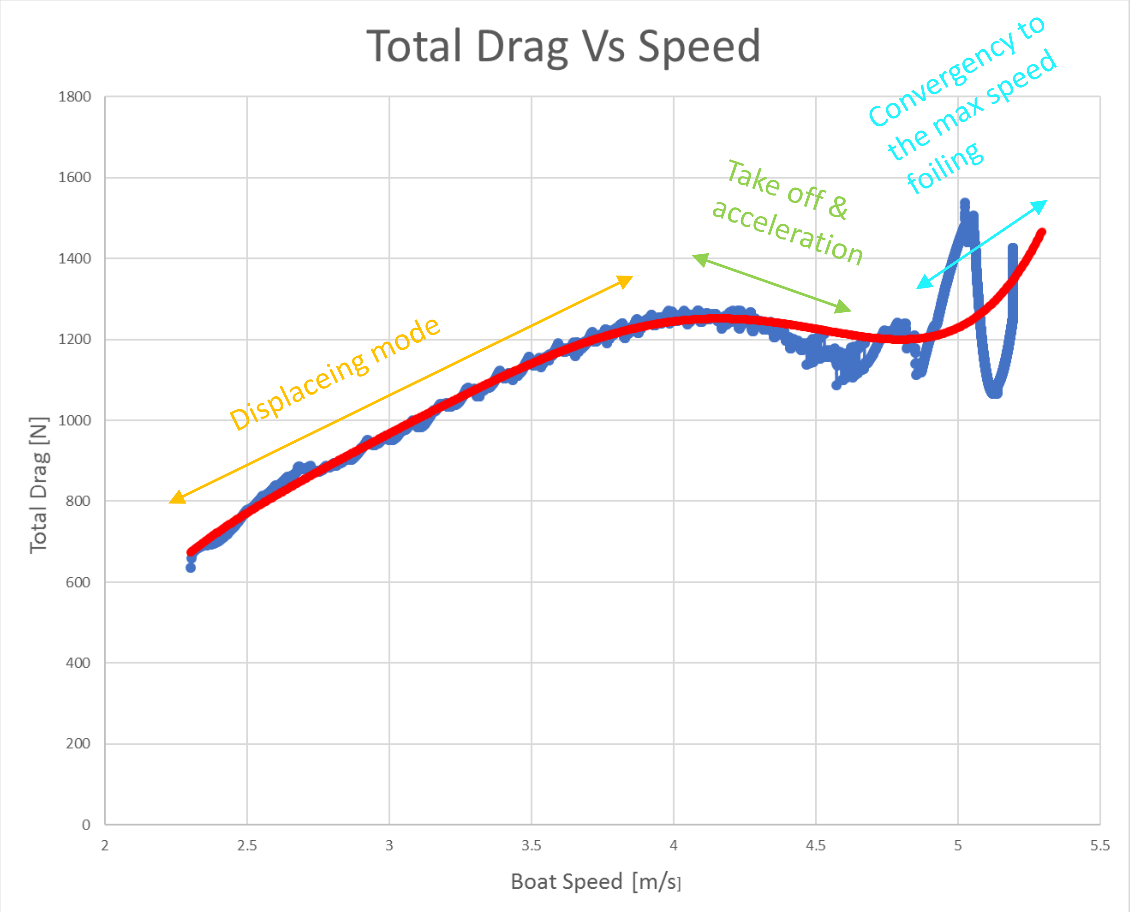
Downwind 6.6 TWS, foiling at 11.0 knots
AWA 35.6. Nearly neutral windward foil

Downwind 15 TWS, foiling at 35.6 knots
AWA 21.2, Dynamic stability at 71% max allowable



Dynamics

In order to compute the system's dynamics, MBDyn, a multibody dynamics simulator developed by the Milan's Polytechnic, has been adopted. Hydrodynamic and aerodynamic loads are computed at each time step by a Vortex Lattice Method software. Viscous drag is also taken into account, for all elements touching water, so the overall drag is fairly represented. A variety of sail shapes can be analyzed, and the sail curvature can be changed during the simulation to better represent the change of sail efficiency with different wind conditions. To ensure the system's stability for the whole simulation, PID controllers tune the foils and rudder continuously. Doing so, the dynamic behavior of a foiling sailing boat can be simulated along with the work needed to foil in a stable way.



The minimum TWS 6 kts has been chosen as significant take off condition to simulate. Simulator has confirmed that in that wind range boat can take off reaching at about 9kts boat speed with the help of CODE 0. Simulation showed also the acceleration to the target max VMG condition at a boat speed of 11 kts and TWA 136°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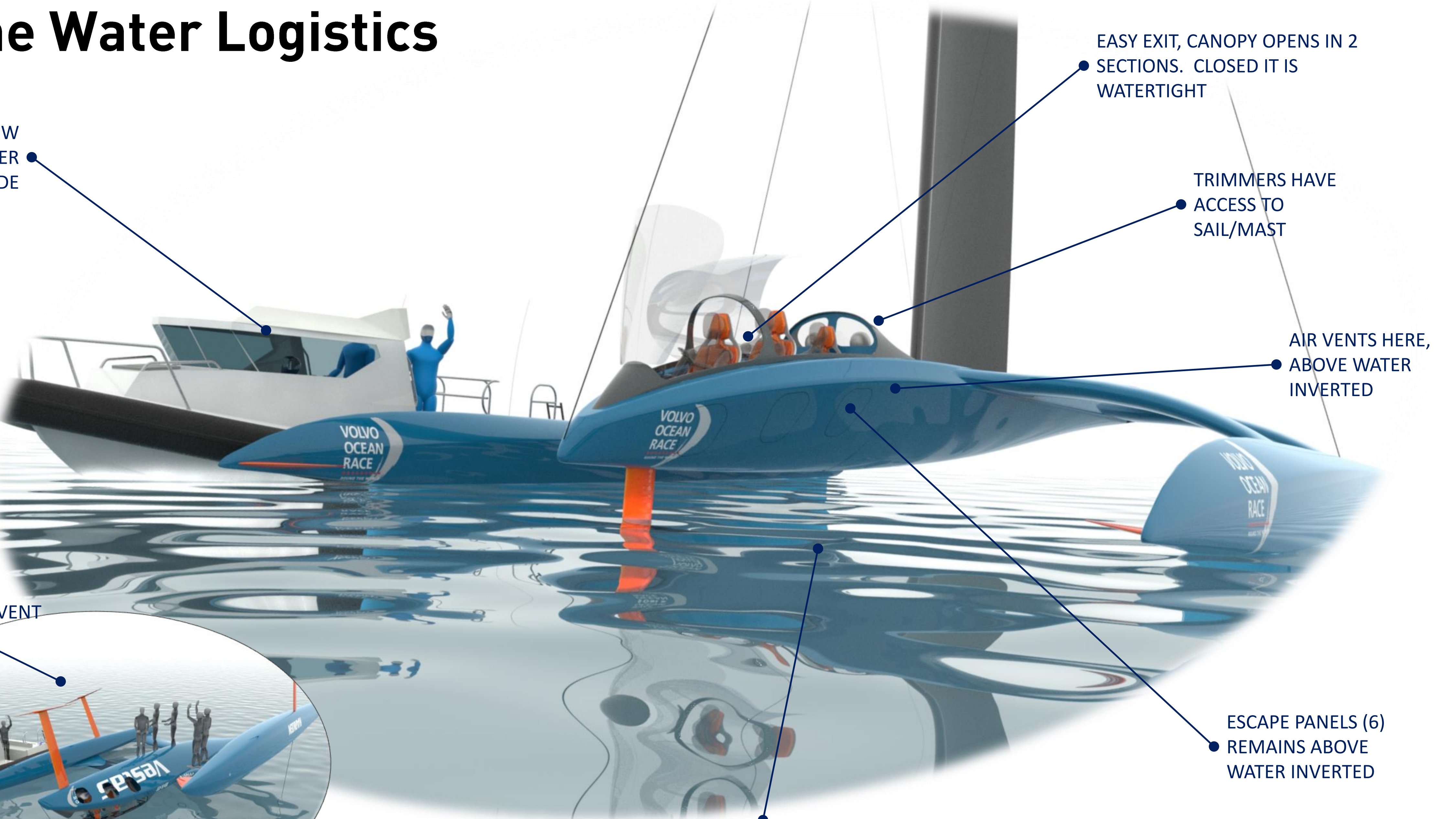
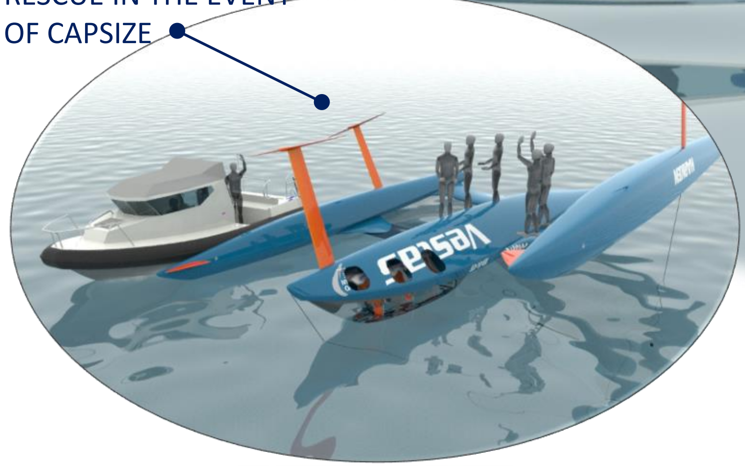
On the Water Logistics





Weight Estimate

Description	Qty	Each	Wt	LCG	VCG
			kg	m	m
Hull mid	2	75	150	4.860	0.100
Hull ends	2	49	97.2	7.470	0.148
Hull Structure	2	25	50	4.383	0.134
Nacelle	1	220	220	5.429	0.871
Canopy	1	15	15	9.305	1.508
Nacelle Structure	1	30	30	5.600	0.800
Cross Beam	1	107	107	5.856	0.966
Cross Beam	1	107	107	1.358	0.809
Fairings	1	39	39	3.410	0.890
Mast/Rig	1	89	89	5.330	9.790
Seats	3	6	18	9.281	0.690
Deck Hardware	1	12	12	5.600	1.240
Winches	2	6	12.4	6.700	1.216
Elec motor	2	8	16	6.700	1.216
Hydraulics	1	34	34	6.400	0.650
Electronics	1	25	25	9.000	0.700
Batteries	1	50	50	5.300	0.700
Rudder	1	55	55	11.100	-1.000
Daggerboards	2	69	139	4.260	-1.500
Electrical Actuator	4	3	10	6.500	0.600
Bow planes	2	5	10	11.280	0.035
Running Rigging	40	0.2	8	6.000	1.100
Main	1	32	32	6.000	8.000
Code 0	1	18	18	6.000	8.000
Furler	1	4	4	11.900	0.600
Margin	4%	1348	54	5.540	1.230
Crew	5	80	400	8.540	0.884
Sum			**1801**	**6.206**	**1.153**

Construction is to be primarily of lightweight carbon sandwich. This weight estimate presented here includes bamboo laminate components for approximate 20% of the platform structural weight. Such laminates have a beneficial carbon balance, and provide an additional safeguard to the racing environment, as these are the most vulnerable to collision and other damage.

Use of only carbon components can save about 70 kg

Ply	Material	Description	Coverage	Roll Direction [deg]	Fiber Direction [deg]	Dry Weight [g/m^2]	Lam Weight [g/m^2]	Thickness [mm]
1	TBD	SURFACING FILM	ALL - OUTSIDE SKIN	-	-	440	440	0.11
2	RC 200	200 g/m2 CARBON WOVEN	ALL - OUTSIDE SKIN	0º	0/90º	200	336	0.23
3	UC 300	300 g/m2 CARBON UNI	MID SECTION	0º	0º	300	473	0.32
4	XC 400	400 g/m2 CARBON DOUBLE BIAS	ALL - OUTSIDE SKIN	±45º	90º	400	671	0.45
5	BOND	CORE BOND	ALL - OUTSIDE SKIN	-	-	250	250	0.20
CORE 1	CORE 43 - 10mm	10 mm Nomex 43	ALL	-	-	430	430	10.0
6	SINGLE SKIN	EST	TBD			3200	5369	3.62
7	BOND	CORE BOND	ALL - INSIDE SKIN	-	-	250	250	0.20
8	UC 300	300 g/m2 CARBON UNI	ALL - INSIDE SKIN	90º	90º	300	473	0.32
9	RC 200	200 g/m2 CARBON WOVEN	ALL - OUTSIDE SKIN	0º	0/90º	200	336	0.23

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Budget

Estimates for design and build have been gathered from two collaborative manufacturers. All figures are in 1000s of Euros. As presented here:

	number	1000 E
Design	1	50
Engineering of Platform and Systems	1	100
Software Development	1	50
Mould Design and Build	1	850
Platfrm Construction	8	340
Appendage Sets (2 sizes)	10	80
Mast and Rigging	8	100
Sails	8	30
Electronics	8	30
Total		5850
Per team		731.25

- Overhead costs are divided over 8 teams
- An allowance has been made for two sets of spare appendages
- Some space remains for both fitout and contingencies
- Spare bows, sterns and fairings are a possibility

The Team

Design Team

Schickler Tagliapietra Yacht Engineering, or ST, is a partnership operating primarily in the marine field, specializing in design and engineering, since 2007. The founding partners have 35 years of combined experience, much of as senior staff at the German Frers (Argentina/Italy) and Bill Tripp (USA/NL) design studios. The fusion grew out of close collaboration in the 32nd America's Cup (2007). ST's specialty is simulation based engineering. Insightful and highly specialized knowledge has been developed through the course of four America's Cup design cycles, (31st, 32nd,34th and 35th), Volvo Ocean Race (2001), and many high-profile race and cruising projects.

Martin Fischer has been working over the past 16 years on numerous top level multihull projects. Most recent work includes having been in charge of the appendage development programme at Luna Rossa (Italian challenger for the 35th Americas Cup) and then Head of Design of the French Challenger Groupama Team France. Beside that Martin was the principal designer for the Flying Phantom (18ft foiling catamaran) and for the GC32 (10 metre foiling catamaran).

Giorgio Provinciali, Born in Milan in 1969, he holds a Degree in Naval Engineering from the Ecole Nationale Supérieure de Techniques Avancées (ENSTA) of Paris and one in Aerospace Engineering from the Politecnico of Milan. In his career Giorgio was involved in developing numerous projects; he specializes in VPP, tank testing and performance analysis. He was a past member of Luna Rossa (2004 – 2007, 2015) and BMW Oracle Racing (2010) design teams. He has also worked for Hydros, and Enata Industries.

Andrea Vergombello, born in Venice in 1983, holds a degree in Aerospace Engineering from the University of Padova and is specialized in computational fluid dynamics (CFD) analysis, 2D section development and VPP studies applied to sailing yachts. Andrea gained specific experience working with Perini Navi, ST and GP Perf&Design Ltd as both CFD and VPP consultant involved in the main stages of different projects. He collaborated with the Luna Rossa Challenge 2013 Design Team as CFD specialist and joined Groupama Team France as a member of the Design Team for the 35th America's Cup.

Viktor Brejcha graduated at Czech Technical University in 2017, majoring in Architecture and Urbanism/Industrial Design. Since 2013 he has worked as independent contractor for individual yacht and design projects, cooperating with international companies, including CompoTech, Sea-Line, C-L Poland.

Franco Lovato is a graduate (2017) of Politecnico di Milano, with a Master's degree in Aeronautic Engineering. He has developed a dynamic performance simulator with Matlab for boat maneuvers, to study how vessels responds to perturbations and control inputs.

The Team

Build and Development Team

DNA Performance Sailing, Holland Composites
Dna is the marine division and service provider of Holland Composites

Developers and builders of successful foiling multihulls, from A Class to the 46 foot F4. Experts in prepreg series production. With our core team of 35 people we build state-of-the-art boats. The organization is as flat as The Netherlands; there is no middle management, we prefer an informal yet professional setting. Our team includes trained engineers, purchasers, boat builders and team riders.

Enata Marine, Hydros
ENATA Marine is the maritime and nautical division of ENATA Industries and acquired the Hydros Innovation in 2016.

The shipyard located in Sharjah offers a wide range of solutions: from flying yachts to cruising catamarans and mega yachts. Specialized in carbon material, ENATA Marine ensures a high quality on every single phase of the production process and is committed to deliver your projects even on a tight schedule.