Foreword

Design is a huge subject, informed by one's outlook, perspective, technical ability, economics, the natural world, or even metaphysical theories - who will be sailing the boat, what level of experience and ability do they have, what are the prevailing conditions, and how the boat is to be used whether it be for casual racing or heavy competition for example. The requirements of the design here are actually quite unique, while there are successful dinghy designs that are good for juniors, adults or beginners, experienced racers, or even the physically handicapped there are few dinghies that will try to do it all - the Wayfarer comes to mind. Traditionally dinghies are designed with a specific customer in mind, whereby the owners athletic ability, body weight, and sailing ability are absolutely clear. Normally this is a very important design consideration as dinghies are ballasted by the crew weight and any increase in potential performanceis usually achieved through increasing the righting moment, more active boat trim, and piling on more sail area, this all amounts to a higher level of physical and sailing ability required to properly operate the boat. Keelboats are not completely subject to these requirements as they are ballasted by the keel, although they are still affected by crew weight to some degree - which in a strange way makes a handicap system (under certain conditions) more fair than one design sailing. Dinghies designed with crew weight and skill as a variable are quite few. Some might remember the Laser designs of the early 90s which included adjustable racks which could provide additional righting moment for lighter crews. Somehow this particular innovation never quite caught on, the trend over time being to offer different rig sizes for the same boat which came with it's own set of complications and still wouldn't adequately provide a level playing field between sailors of differing body types and weights.

The TPR-1 is designed for sailing schools, and clubs for anybody to sail. Ease of use, comfort, and absolute superlative sailing characteristics in all wind ranges. That means great pointing/footing, acceleration in lighter wind, planing ability in higher wind ranges, while keeping your feet dry, and not getting exhausted at any point. Of course there is no reason why such a boat could not also be appealing to potential buyers.

Ordinarily performance on a dinghy is dictated primarily by stability, sail area and displacement, hull form is secondary. A designer will attempt to maximise stability and sail area while minimizing hull weight and wetted surface to achieve the best performance. The best example of this would be a skiff, huge racks huge sail area, very light hull. If we take the trapeze and the racks out of the equation we are left only with the shape of the hull to provide stability through beam, this leads to the proliferation of delta shapes/wide transoms or also high prismatic hulls fat al the ends . The idea being the increased drag at low speed can be balanced out by piling on even more sail area, and good boat trim in light winds. In heavy winds the negative becomes a positive by introducing a large aft planing surface. In that way logically for a dinghy the best choice would seem to be to design a boat for heavy air and leave it up to the sailors to sail as best they can in light air with good boat trim, and a hull that is a bit more draggy and a large sail area. This is perfectly good, but relies on all three elements to be in balance. For example a dinghy with a heavy hull, large sail area and highly unstable hull form would have erratic sailing characteristics, poor performance in gusty conditions, poor acceleration, and also unstable as weight and drag prevent the boat from accelerating in the gusts as driving moment is converted to heeling moment.

While piling sail area onto a hull form will improve the performance it also creates a boat that responds erratically which raises physical and mental demands on the crew. For a boat designed to be physically easy to sail the goal should be to create a low drag hull with good form stability that can be sailed effectively with the least possible sail area while still maintaining enough sail area for very good light air performance.

Requirements

The boat is designed to serve 3 functions:

- Training boat
stable, handleable, durable
- Pleasure boat :
easy to sail, fun, comfortable, stylish
- Racing boat
good sailing characteristics (manoeuvrability, acceleration)

- The boat must be suitable and fun for users of all sailing ability and posses good sailing characteristics in all conditions .
- The boat must be tough enough to require only an absolute minimum of maintenance from season to season.
- The boat must be self *draining* (not self bailing).
- The boat must be able to hold 3-4 full grown adults, or up to 8 children.
- The boat must be narrower than 6' because of dock limitations.
- The rig must be able to pass under the bridge, which has a height of X.
- The boat must be easy to manufacture.
- The boat must be stable enough to be boarded easily and safely.
- The boat must be able to easily accommodate a weighted daggerboard for the physically impaired (unfit, overweight, or otherwise).

• ***Introduction***

• We can define suitability as a function of size and power. An Optimist for example is a boat with relatively low power (having a power ratio of around 18) and as such is suitable for sailors of low skill and low athletic ability however it's small size makes it unsuitable for adults of similar ability. A large heavy cruiser with a similar power ratio may easily handled by an adult with low sailing and physical ability, but its large size makes it unwieldy for children. The solution is to have a boat of relatively low power, which is large enough for adults and not too large for children. To satisfy requirement 1 we must consider what we mean by fun. In light wind fun can be defined as responsiveness and acceleration/break away speed. In moderate and heavy conditions fun is a funtion of planing ability, pointing ability, comfort and safety. It should also be mentioned that boats with lower freeboard will appear to be more fun due to being closer to the water. Therefore the design should strive to keep the freeboard low.

• Toughness can be defined as damage resistance for our purposes. This can be achieved by three methods: material, structural, design. Choosing tough, materials which are also light and stiff, arranging it into a form that is structurally resistant to damage and deformation, in such a way that takes into account how the boat will be used which integrates the design element. For instance the bow can be built flat and even fitted with a moulded silicon bumper to prevent damage.

• The boat must be capsizable and self draining, water must be able to drain from all parts of the hull.

• Capacity maximization, buoyancy and cockpit size : hull form affects the ability of the boat to carry a load which is greater than would normally be required.

• B2S specific requirement due to dock limitations should not exceed feet in beam.

• Alte Donau design specific limitation, this puts a hard limitation on mast height. Mast height must in this case me maximized and fixed whereby other critical measurement may remain variable such as boom length and J measurement. Important considerations for the rig are the sail area, fractional ratio and the mainsail aspect ratio.

• An Alte Donau specific limitiation, due to the presence of debris.

• By ease of manufacture it is meant that the boats should be able to be built by the amateur builder with a high level of consistency.

• B2S specific requirement due to how the boats are docked.

• The boat must have a daggerboard to allow the insertion of a weighted daggerboard if need be for customers that are physically impaired.

Noticeable Design Features

The boat has some noticeable design features:

• Hard chine from bow to stern
• Flat bow stem
• A flat spot running from bow to stern
• Concavity

• The hard chine provides higher initial stability, as the boat heels the volume of the bilge is introduced very suddenly rather than gradually with a round bilge. This will make the boat easy to board and comfortable to move around on at dock. Chines, which were at one time considered old fashioned have now become commonplace in modern performance sailboats. This is a great example of how adopting a particular design feature simply because its modern, can lead to having a boat that looks actually old-fashioned in a few years. Trends change and design features that are modern now might not be modern tomorrow. By adopting current trends for marketing appeal a designer could inadvertently causes his design to look dated later on. Current thinking is that when a boat presents a hard chine to the water there is a pressure difference between the bottom of the hull and the topside. As the water is sucked out from the bottom the chine enables it to break away cleanly and maintain laminar flow, whereas a round chine will cause turbulation as the two pressures mix. That is why the hard chine after being abandoned for so long has begun to re-proliferate.

• In the forward sections a hard chine may be somewhat undesirable some of the time, the pressure created by the centreboard creates a low pressure area on the windward side which sucks the water at the lee bow under the boat. Softening the chines in the forward sections will allow the boat to suck in the oncoming water. To solve this problen the chines in the forward scetions are raised off the waterline.

• Concavity is a design feature that has been around forever, it enables the beam and buoyancy to be kept more towards the middle rather than at the ends where it would create drag at low speeds and higher displacements. It was prolific in fast designs of the all eras where material technology made boats heavy by today's standards. Some racing designs also have this feature notably the Flying Dutchman, however as boats became lighter and more powerful it became less prolific. Still such designs are always admired for their graceful lines.

Design Hydrostatics.

Design length	:	*18.000 [ft]*
Length over all	:	*17.200 [ft]*
Design beam	:	*5.300 [ft]*
Beam over all	:	*5.643 [ft]*
Design draft	:	*0.500 [ft]*
Mainframe location	:	*9.000 [ft]*
Water density	:	*63.989 [lbs/ft3]*
Appendage coefficient	:	*1.0000*

Volume properties:		
Displaced volume	:	*10.305 [ft3]*
Displacement	:	*0.294 [tons]*
Total length of submerged body	:	*14.804 [ft]*
Total beam of submerged body	:	*4.763 [ft]*
Block coefficient	:	*0.2923*
Prismatic coefficient	:	*0.5434*
Vert. prismatic coefficient	:	*0.4454*
Wetted surface area	:	*47.595 [ft2]*
Longitudinal center of buoyancy	:	*8.744 [ft]*
Vertical center of buoyancy	:	*0.342 [ft]*
Midship properties:		
Midship section area	:	*1.281 [ft2]*
Midship coefficient	:	*0.5379*

Waterplane properties:

Length on waterline : 14.804 [ft]
Beam on waterline : 4.763 [ft]
Waterplane area : 46.270 [ft2]
Waterplane coefficient : 0.6562
Waterplane center of floatation : 8.373 [ft]
Entrance angle : 90.000 [degr.]
Transverse moment of inertia : 59.099 [ft4]
Longitudinal moment of inertia : 503.88 [ft4]

Initial stability:

Transverse metacentric height : 6.077 [ft]
Longitudinal metacentric height : 49.240 [ft]

Lateral plane:

Lateral area : 5.032 [ft2]
Longitudinal center of gravity : 9.033 [ft]
Vertical center of gravity : 0.297 [ft]

The following layer properties are calculated for both sides of the ship:

Layer	Area [ft2]	Thickness	Weight [tons]	COG X [ft]	COG Y [ft]	COG Z [ft]
bottom	3.936	0.000	0.000	0.000	0.000	1.365
cockpit floor	36.394	0.000	0.000	7.136	0.000	0.873
cockpit sides	43.790	0.000	0.000	8.366	0.000	1.509
tumblehome	9.504	0.000	0.000	7.802	0.000	1.951
bow stem	0.460	0.000	0.000	16.920	0.000	1.363
keel	7.152	0.000	0.000	7.840	0.000	0.195
topsides	44.721	0.000	0.000	8.918	0.000	1.215
bottom	54.597	0.000	0.000	7.376	0.000	0.371
deck sides	18.217	0.000	0.000	8.071	0.000	2.119
Total	218.77		0.000	0.000	0.000	0.000

Sectional areas:

Location [ft]	Area [ft2]
0.900	0.000
1.800	0.044
2.700	0.170
3.600	0.353
4.500	0.574
5.400	0.807
6.300	1.018

7.200	*1.178*
8.100	*1.267*
9.000	*1.281*
9.900	*1.227*
10.800	*1.110*
11.700	*0.937*
12.600	*0.710*
13.500	*0.457*
14.400	*0.222*
15.300	*0.062*
16.200	*0.000*

NOTE 1: Draft (and all other vertical heights) is measured above the lowest point of the hull! (Z= 0.079)
NOTE 2: All calculated coefficients based on actual dimensions of submerged body.

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Analysis of hydrostatics

$\sqrt{WL} * 1.34 = \text{Hull Speed}$

$\sqrt{14.8} * 1.34 = 5.15\text{kts}$

$$\frac{\text{Velocity}}{\sqrt{WL} * 1.34} = \text{Speed to Lengh Ratio}$$

PRISMATIC COEFFICIENT

The following explanation was taken from the Kasten Marine web page and offers a great explanation and partial analysis:

“The prismatic coefficient is the ratio of actual underbody volume to the volume of a prism having a length equal to the DWL, and a section equal to the boat's maximum sectional area. The prismatic coefficient provides an indication of the distribution of displacement. It is an indication of the fineness of the ends relative to the midsection of he hull. A low prismatic means there are fine ends and large mid-body. A high prismatic means there is more displacement distributed toward the ends. Since the fullness or fineness of the ends has a large effect on wave making resistance, for any given speed to length ratio there is an ideal prismatic coefficient. As speed increases and the bow and stern waves rise, additional buoyancy in the ends becomes more favourable. Since racing yachts are more often driven at higher speeds, they benefit from a higher prismatic. Optimum prismatic coefficient depends on the expected speed range.

Philips-Birt and others suggest that it is better to err on the high side in order to allow the least penalty at higher speed, since light wind sailing suffers less from a high prismatic than fast sailing suffers from a low prismatic.

Sail Opinion varies regarding the range of ideal prismatic coefficients. Most sources suggest that for average conditions, the optimum prismatic is between .54 and .56.

- *Light winds and calm water favour a lower range of about .53 to .55.*
- *Heavy winds and ocean sailing favour a higher range of about .55 to .58.*

A higher prismatic provides greater buoyancy in the ends and improves pitch dampening.
An asymmetric water plane also improves pitch dampening, as does having some separation between the center of the water plane and the center of buoyancy."

Our design has a prismatic coefficient of .56

Initial Stability

Angle of heel= 5 degrees
GM = 6'
GZ = .5229'
Displ = 580 lbs
*Gz * Displ= Buoyant Force*

*6' * (sin.5degrees) = .5229'*
*.5229' * 580 lbs = 303.3 lbs*

Righting Moment 303.3 lbs

The boat will heel 5 degrees when one crew member of 150 lbs stands roughly two feet off centerline. That is very good initial stability however this stability at dock will decrease slightly with the addition of a rig. Indicating the boat will be safe to board at dock and stable on the water which satisfies Requirement 9.

• ***SA***

Requirements 1&2 deal with a boats SA/Displ ratio, other factors not included in the formula are beam, waterline beam, bilge volume, prismatic coefficient, longitudinal center of buoyancy, freeboard height. Since the power of a design is important when deciding on the suitability of a design an analysis of existing designs will help us to determine ideal numbers for our requirements.

SA/D range of values:		*16 to 18* *18 to 22* *22 to 26* *26 to 30+*		*Heavy offshore cruisers* *Medium cruisers* *Inshore cruisers, racing boats* *Extreme racing boats*

Crew weight was determined by what I believe to be an average crew weight for the boat.

Adult 150 (except for laser where it was 170)

Child 100

Youth 125

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            Sail Area in sq. ft.
SA/D = ----------------------------------
            (Displacement / 64)^0.6666
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SA/Dsp

Optimist - 35 / 177 = 17
Pirat 108 / 500 = 20
RS Feva 90 / 390 = 27
Laser 76 / 300 = 27
420 110 / 450 = 30
470 137/ 560 = 32
Tasar 120/450 = 33
Omega 160 / 650 = 34
Flying Dm 204/ 663 = 43

Since all boats measured are dinghies and not keelboats, balance must be maintained by crew weight this means the ratio can be seen as the raw physical and technical demands of being able to sail the boat properly, alternatively it can also be seen to represent the fun factor. Lower number equals high accessibility/ low fun; while high numbers represent high fun low accessibility. The Omega and the Tasar are somewhat outliers in this data set due to the very light hull weight of the Tasar and the large sail area of the Omega. Still these ratios can be used to make rough estimates of what one can expect from a design.

SA and Rig Choice.

The biggest performance factor will be determined by rig selection and sail area. Because the boat must be comfortable to sail in all conditions the concept for the boat will be to build a very light, durable design with a highly efficient geometry and as little sail area as possible while still maintaining good light air performance. A small highly efficient rig will will keep the boat controllable through the entire wind spectrum while a light hull will keep the boat lively and fun to sail. A trapeze can also be added to help particularly small junior sailors in heavy air. Also special attention should be given to keeping the boom short' and the mast a high as possible since it is limited by the height of the bridge. A short boom has the advantage of making the boat more manageable in gusty conditions as the centre of effort is kept closer to the centre of lateral resistance. This will also increase controllability downwind as the centre of effort remains inboard as the sail is eased out. The mainsail profile should maximise upwind performance when the sail is generating lift and minimise downwind performance when the sail is acting in resistance. This will make the boat manageable downwind in windy conditions for beginning students and promote the use of the spinnaker or asymmetric for progressing students and racers. For this reason flat top or highly roached sails would be disadvantageous to the design concept. What the sail plan will look like in the end must be decided upon after careful consultation with the sailmaker and the supplier. Presumably some form of ¾ fractional rig 4 to 1 aspect ratio with a non overlapping jib and single spreader with the option to reef the mainsail for small children and absolute beginners in heavy wind. When reefed the sail plan should have about the power of an Optimist, approximately calculated at 70 square feet in total. Total upwind sail area should be around 110 square feet. The end result is a boat which should be easy to control for beginners, fun to sail for the intermediate sailor, and highly mentally engaging for the advanced racer while remaining physically easy to sail in all wind ranges.

Asymmetric vs Conventional Spinnaker

While the symmetric probably offers better performance for a boat with such low power and a small sail plan the asymmetric offers ease of use and practicality. Both have pros and cons – an asymmetric will need to have a bowsprit which takes up space in the boat and requires extra steps to build as the sprit passes through the bow of the boat or must be mounted somewhere else where it will also be taking up space where passengers could be sitting. The narrowness of the Alte Donau is also a factor which would lend itself to the adoption of a conventional spinnaker, enabling the boat to sail deeper and avoid the edges where the wind is flukey and damage can occur. What the asymmetric offers is ease of use and some marketing benefits towards potential buyers or customers as it portrays a very modern image. Ease of use is a design requirement and things which are easy to use tend to be used for longer than things which are cumbersome to use. On the other hand sailing with a conventional spinnaker may not be technically easier may be physically easier. A boat sailing an asymmetric at the same VMG will inevitably sail the downwind leg at a higher angle to the wind this will force the crew to continue to hike out rather than getting a rest on the downwind. This may not be a factor for a young crew with boundless energy, but for a middle aged crew and above it will factor in to how long they remain on the water and how often they will go sailing. For this reason I tend to favour a symmetrical spinnaker as even a young crew will not stay that way for very long.

Deck Layout and Cockpit Design

The boat should have an innovative cockpit and control system.

- ***The Main Sheet***

The main sheet should be trimmed off the boom similar to a 49er so that the sail can be trimmed from any part of the boat by any member of the crew or instructor. This frees up cockpit space and will be a great tool for instructors. In racing mode the main sheet can be snapped in to a carabineer attached to a line coming off of the cockpit floor this may provide increased controllability for racing situations and is easy to undo.

- ***The Vang***

The main sail should be fitted with a compression strut style vang system or *gnav*. Getting the boom vang out of the cockpit will free up extra cockpit space, which means increased comfort and capacity.

- ***The Daggerboard***

The daggerboard trunk should be under the deck so that the top of the daggerboard is flush with the cockpit floor. The top of the daggerboard could even drop into a cockpit floor recess to make the entire setup totally smooth with no protrusions, this will increase comfort. Daggerboard operation could be done by a DB halyard mounted on the mast under the boom for easy clearing of debris or it could be simply done by hand. The boat could have an extra weighted Daggerboard that could be deployed for physically disadvantaged, or very young customers to make the boat more comfortable.

- ***Jib Leads***

The Jib leads should be operated via a bridle system, this will allow for complete control over sail shape. When the jib is dropped the bridle ring lays on the cockpit floor and allows the crew to easily get around the boat. For beginning students the bridle adjustment can be marked and set

- ***The Jib***

The jib should be mounted on the forestay with hanks or roller furling. Hanks are cost effective, easy to operate, suitable for all skill levels and quick to drop and hoist. A roller furling system is also a good option but is more expensive.

- ***The Cockpit Seat***

The cockpit seat should be lightweight and run laterally between the sides of the cockpit. The seat should be easily removable via pin. This will increase capacity and allow small children or less mobile adults a place to rest comfortably inside the cockpit when used for training.

8. The Self- draining Cockpit

Requirement 4, from a design perspective is quite simple. As long as the volume of the cockpit is less than the volume of the buoyancy compartment under the deck the boat will not sink. Once the boat takes on water, the boat should be able to self drain as long as the cockpit floor does not allow the water to pool, and remains above the waterline. This should require some model testing as it is absolutely critical to the effectiveness of the overall design. These tests would be very simple to evaluate as its very easy to determine if the boat is draining. A self draining design has many advantages. The cockpit is always kept dry which makes the boat more comfortable, the boat does not need to be pumped, the buoyant design will aid in seaworthiness, and assist in capsize righting. The requirement for the boat to be comfortable and have a expanded load capacity is also relevant to the self draining cockpit design. The cockpit floor should be deep enough to remain comfortable but also remain above the waterline.

Closing

In the end what I have presented is in no way a radical design, it is also not a hum drum amalgam of compromises. The design attempts to present a concrete direction forward for sailors of all levels. I tried to evaluate the usefulness of every design feature a dinghy could have to the requirements of the design and select what provably and logically works. In admittedly I tended to downplay other factors such as trend, image, and marketability, however I feel this speaks to the overall strength of the design concept as these considerations can be adressed in other phases of the project.