Building 8-ft model sailboats

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[with references to D. Loibner's "The Folkboat Story]

This is a proposal for engineering students at Lake Campus to build four scale model sailboats, approximately 8 feet long. The boats will be eventually sailed by remote control and robotic self-steering. And they will be put into hostile storm conditions. However, initial investigations do not require robotics. The boats could be steered by rudder via strings from a pontoon boat travelling along side. Initial studies of survival in bad weather can be achieved by anchoring the boat a few meters off shore (before a storm) and watching the action during the storm.

Who is being served

One must tread lightly with state-funded yachting in a nation as fiercely entrepreneurial as ours. I have received over $2,000 in private donations from local to build small and primitive wooden sailboats. The intent by these local donors was presumably to make Grand Lake a better place. In building two small "sailing barges" with these funds, I tried to make unusual boats that have never been built; in the hopes that such efforts to innovate might eventually add to the knowledge of amateur home boatbuilding everywhere. I believe the nourishment of such activities should be part of a university's mission, even though this is not traditional "physics" research. Also, the effort to do what has never before been done is an essential aspect of science, and should be an integral part of science education, whenever possible.

The scope of this proposal does not involve actual sailboats, but the design and construction of 8-ft scale models with automated self-steering. The intent is to teach students about engineering; to give students experience in (1) the scaling of dimensionless parameters, (2) computer aided design (CAD), and (3) robotic technology. Also, the project has true and useful purpose, since it is ultimately directed at a real sailboat that might someday be designed and built. I call this proposed sailboat the ***home-built offshore pocket cruiser***.

Concerns about pollution, cyanobacteria, safety and insurance associated with actual sailing by university students on Grand Lake are greatly diminished if we instead study model sailboats. Furthermore, model boats are much cheaper and also provide students with more learning opportunities. For example, it is far more feasible for students to actually build boats they design if the cost is kept low by restricting ourselves to 8-ft models. I choose this size because the appropriate thickness for the plywood is that of the extremely cheap luan underlay (3/16 in).

A short history of the offshore pocket cruiser

Engineers often find themselves at the interface between science and technology on one side, and human interests and aspirations on the other. This is certainly the case in the "sport" of amateur boatbuilding. Since hundreds of designs are available for the home boat-builder, the would-be creator of a new design must look hard for an unfilled niche. One such opportunity to innovate is the *offshore pocket cruiser*: "offshore" hints at ocean crossing capabilities without implying that this is an intended purpose; "cruiser" establishes that there must be sleeping berths. The proposed boat is trailerable, and hence "pocket". Such boats capture the imagination. The 22 ft Glen-L designed Amigo was what agent Gibbs was building in his basement in the TV series NCIS.

The quintessential offshore pocket cruiser is the classic 25 foot Nordic Folkboat, which emerged from a design contest conducted by Scandinavians in the depths of WWII. Affordability was an important consideration that probably led to the boat's small sail area relative to the boats massive displacement. Ironically, this probably enabled the class managed to survive over the years as virtually all other classes of that era fell into disuse. The conservative sail area, combined with the narrow beam, long keel and massive 50% ballast, all gave the Folkboat extreme seaworthiness. The class rules stipulate that the cabin holds three sleeping berths. After the war, brave individuals began to make impressive passages in a cruiser originally intended to race in more sheltered waters: "Blondie" Hasler made the first of four passages to New York in the Singlehanded Trans-Atlantic race, starting in 1960, always sailing back on the boat's own keel. In all, Hasler's folkboat *Jester* successfully crossed the Atlantic Ocean 12 times before meeting her demise after a series of knockdowns 470 miles off the coast of Halifax in 1988. Fortunately, *Jester's* new owner and sole crew member, Mike Richey, was rescued on this 13th attempt. In 1975, Ann Gash, an eccentric 55 year-old grandmother with little sailing experience, sailed from Australia to England (and almost back) ostensibly to attend a music class with the British Guild of Bamboo Pipers (she also survived). A production built fiberglass version of the Nordic Folkboat crossed the Atlantic as recently as 2007. Active Folkboat clubs can be found today in Sweden, Germany, Denmark, Finland, England, and San Francisco.

These stories are important because they might inspire local area students to experiment with robotic self-steering devices, investigate the performance of unmanned models in rough weather, and use CAD software to design the *home-built offshore pocket cruiser*.

Engineering Skill #1: Dimensionless Parameters

It is essential that an engineer has a strong intuitive understanding of how equations are used in design, and few are as important as those involving dimensionless parameters. The Froude number is $Fr = \sqrt{L/gT^2}$, where T is time, L is length, and g is the gravitational acceleration. The Froude number governs the interactions that involve Earth's gravity: how animals walk and run, how a tree or chimney falls after it has been cut, and how a boat interacts with waves, provided turbulence, viscous effects and surface tension are not important. Froude scaling is easy to study in boats using wave tanks, and allows scale models to predict the behavior of the real thing.

 selfright  Anita im Orkan

Both videos viewable at: http://www.wright.edu/~guy.vandegrift/Talks/index.htm "A working sailing barge for …"

The video to the left is slowed down a factor of 6, making it a rendition of how an extremely heavily ballasted 30-ft sailboat would right itself if placed bottom up in the water. (Actual sailboats are not nearly this well ballasted and would generally stay inverted under these conditions.) The other video shows the yawl *Anita* struggling in heavy seas under a single jib. Under normal sailing conditions, forces on the sail are governed not by Froude scaling, but instead by Reynolds scaling, $Re = LV/\nu$, where ν is kinematic viscosity and $V = L/T$ is velocity. Reynolds number is essential to sail (and keel) design because *lift* is so important. Reynolds scaling requires either a wind tunnel or an equivalent system that uses a large pipe with evenly flowing water. But *Anita's* problem is the waves, and hence Froude scaling almost certainly dominates. "Armchair" sailboat designers like to think in terms other dimensionless parameters.

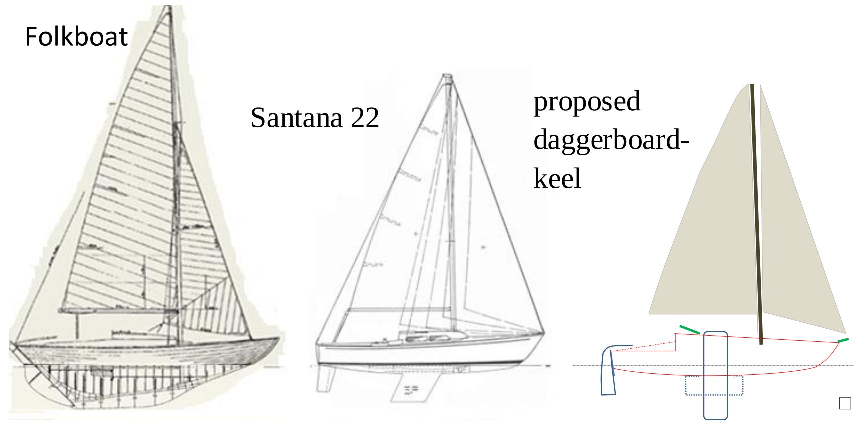
- D/L = (*disp* / 2240) / (0.01**LWL*)^3 -- Displacement Length (*LWL* is at waterline)
- SA/D = SA / (*disp* / 64)$^{2/3}$ -- Sail-Area Displacement Ratio
- CSF = *beam* / (*disp*/64.2)$^{1/3}$ -- Capsize Screening Formula
- BR = *ballast* / *disp* -- Ballast Ratio
- $/# = *cost*/*disp* -- "bucks per pound" **Not dimensionless, but useful in this proposal's budget!**

Here, *disp* is the displacement in pounds, while *beam*, *sail-area* (*SA*), *draft* are all measured in feet. All but the last two parameters are described at http://dan.pfeiffer.net/boat/ratios.htm. The "bucks per pound" is needed to look at the "competition" to any design for a home-built boat. This competition consists of production fiberglass boats (both old and new), as well as other designs available for the amateur boat-builder. If we can't design something *better*, we can at least look for an unfilled niche and do something *different*!

Engineering Skill #2: Computer aided design

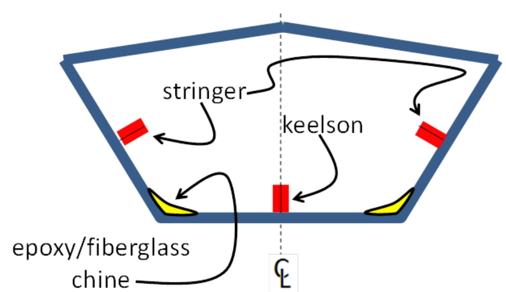
After contemplating a number of successful production and homebuilt pocket cruisers, I have concluded that the dimensions, ballast, and displacement, must all fall in a rather narrow range. This pocket cruiser will be almost the same size, much lighter, and quite a bit less "offshore" than the venerable folkboat. (Otherwise it will be too expensive, a royal pain to build, and un-sailable on Grand Lake). The proposed boat closely resembles the *Santana 22*, a racing class designed for the windy conditions of the San Francisco Bay. For more seaworthiness, we want a keel that goes deeper than the Santana's for ocean work, but can also be made much shallower in shoal waters like

Grand Lake. Adjustable or retractable keels and centerboards are far too fiddly for a serious cruising boat, especially one that is home built. Therefore the keel will be a sort of "daggerboard" that passes through the body of the boat's cabin. Weighing about 1000 pounds, it will not be moved while sailing or even launching the boat. (Though not simple, a 22-ft keelboat can be trailer launched.) With this daggerboard keel, it should not be too difficult to remove, inspect, or replace the keel while in dry dock. Nobody wants to wonder if something is rotting at the bottom during a long passage! It must be understood that changes in the keel's configuration will be a major overhaul, not to be done more than once every year or two. With the area in the center extending from sole to ceiling, the cabin will feel cramped - no place to swing a cat. But cramped quarters are actually safer when people are being tossed about in a storm.



The boat must be very simple below the waterline, without skegs or other structures that can soak up water. The bottom should be coated with a thick (expensive) layer of marine epoxy and several layers of fiberglass. This "offshore" boat needs to be capable of *living* in the water and not dry sailed as are most boats of this size. If the cabin gets soaked during a passage, it must find a way to dry out naturally when the seas become calm. The dock at Lake Campus is ideal for the investigation of how a boat that stays in the water can self-ventilate. This dock is a resource that most amateur boatbuilders lack, and we should take advantage of that by keeping the 8-ft model boats moored throughout the sailing season.

With the size and shape of this boat more or less stipulated, students can go to work on Solid Works (CAD software) and design the boat. I believe that the construction should be "chine logs" (stitch-n-glue) laid over transoms and stringers made from laminated plywood, which should be both cheap and simple to build. The boat must contain enough Styrofoam to be self-buoyant if the hull is ruptured. This buoyancy should permit us to design a boat that is slightly lighter, and hence more flimsy and also less expensive, without diminishing safety at sea. On the other hand, we want the boat to be as stiff as possible; because I would imagine that the flexing of a boat at sea degrades the semi-waterproof epoxy coating and causes the plywood to become damp, which invites rot.



Engineering Skill #3: Robotics and self-steering with sensors.

Here it is important to understand that the robotics will be simple and suitable for college, or even high school students. The design of successful self-steering in gentle conditions dates back to Hasler's *Jester* , which used levers without electronics or servo systems to deliver energy from a wind vane to the tiller. Now most coastal cruisers use electronic sensors on a weathervane and a servo-mechanism to keep the boat at a desired heading to the wind.

In a really serious storm, the crew of an actual pocket cruiser is likely to not be steering at all, but instead be hiding from lightning inside the cabin while they contemplate a lifetime of sins. With an 8-ft model boat on Grand Lake in a thunderstorm, we can just let the thing flail around, perhaps using a sea anchor or sails "hove to" in order to keep it near the shoreline as we attempt to capture the action from a land-based video camera. Remote control might be used to position the boat before the storm, and if we are lucky, to drive it back to shore when the storm passes.

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Refereed Publications:
1. Vandegrift, G. 2008. "The River Needs a Cork", **The Physics Teacher** 46 (7):440
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Budget

Oddly, we don't seek how **much it costs** to build an 8-ft model boat, but instead how **much it must cost** to build the actual 22-ft offshore cruiser **if it is to have a significant impact** on the home boatbuilding community. The 8-ft model described in the following spreadsheet represents exact scaling from the Santana 22 (LOA means length-overall). My guess is that after haggling with the dealer, you could walk out with a brand new fiberglass Santana for 20k$ (i.e., $20,000.) The 8-ft model is shorter than the Santana by a factor of 2.75 so that both the cost and weight would be smaller by that number cubed (at perfect scaling). So this hypothetical company would retail its hypothetical fiberglass 8-ft boat weighing 125 pounds at $1000, or 8 $/# (dollars per pound). The boat would carry 59 pounds of ballast in a keel that extends 1.3 ft below the waterline. In the hypothetical used market for these boats, you would get a used 8-ft fiberglass one in excellent condition at half the price of a new one, at 4$/#.

boat	LOA	LWL	BEAM	DRAFT	DISP	AREA	BAL	SA/D	D/L	lwl/B	CSF	BR	$/#	k$
scale model	**8.0**	**6.8**	**2.8**	**1.3**	**125**	**29**	**59**	**18**	**178**	**2.4**	**2.3**	**47%**	**$ 8**	**1.0**
wp-19	18.8	16.3	7.5	3.6	1225	117	300	16	126	2.2	2.8	24%	$16	20
cal 20	20.0	18.0	7.0	3.3	2040	196	875	19	156	2.6	2.2	43%		
cat capri22	22.0	20.0	8.2	4.0	2200	229	650	22	123	2.4	2.5	30%	$ 9	19
Santana 22	**22.0**	**18.7**	**7.8**	**3.5**	**2600**	**217**	**1230**	**18**	**178**	**2.4**	**2.3**	**47%**	**$ 8**	**20**
Folkboat	**25.2**	**19.7**	**7.3**	**3.9**	**4321**	**258**	**2293**	**16**	**254**	**2.7**	**1.8**	**53%**	**$13**	**55**
Dana 24	24.2	21.4	8.6	3.8	8000	358	3200	14	364	2.5	1.7	40%	$19	150
Contessa 32	32.0	24.0	9.5	5.5	9500	433	4500	15	307	2.5	1.8	47%	$23	220

What is the value of a new homemade wooden boat compared with a used fiberglass boat in excellent condition? Any serious sailor would pick the used fiberglass boat every time. But the romantic will MAYBE choose to build the wooden one. I therefore calculate that a reasonable cost for four 8-ft, model boats would be:

$$(4\ boats)\left(\frac{125\#}{boat}\right)\left(\frac{4\$}{\#}\right) = \$2000$$

<u>That is my request.</u>

Appendix/Footnote: You can learn a lot about offshore boats just from the numbers. The exact shape of the hull is not important because offshore cruising is not about going fast, but just getting there. Causes of failed passages are #1 storms , #2 wear and tear, and #3 mistakes (I think these are in reverse order, with the latter being by far the most common). Though good boats, two don't really belong on the list, as can be seen by their BR, or ratio of ballast to displacement. Although there is nothing wrong with a BR of 20%, a purist might view the Wight-Potter 19 and (to a lesser extent) the Catalina 22 Capri as hybrids between true keelboats and boats with heavy centerboards. (The boat owned by Lake Campus is not much different than the Capri.) With a D/L of only 178, the Santana is perhaps too light to be called offshore. It should be noted however, that both the WP-19 and Santana have made it from California to Hawaii.

The "cal" in the cal-20 stands for "California" and is an old boat I remember from the 1970s. It went into production in 1961. The Santana 22 was designed to be an "upgrade" to the Cal-20, and apparently its designer succeeded. Cal-20s are still popular in the San Fransisco Bay Area but only as old vintage boats; none are in production today. The Dana 24 an ultra-expensive heavy boat, still in production, though not many are bought. The Contessa is still in production but at a very hefty price. It first went into production in 1970, and is highly regarded in Europe as a sort of "supersized" folkboat with a modern fin keel. Except for the Cal-20, all the boats in the list are still in production, though all but Santana (and of course the Capri) would tend to be viewed as a bit pricy. Cheaper, lighter, and faster production boats are quite suited for the sailing that most people do.