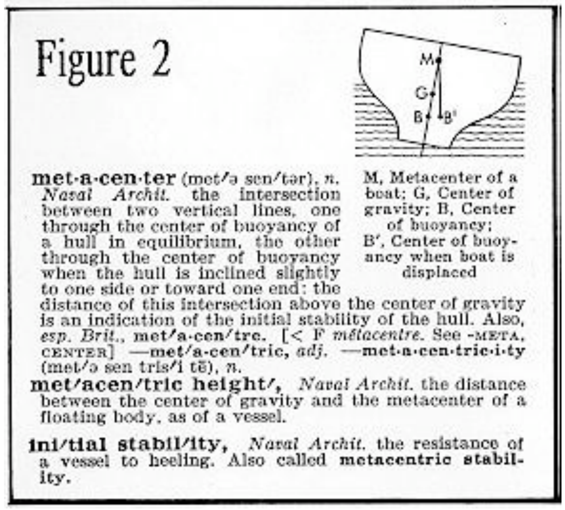
HULL STABILITY

Editor's Note: This article is written by Richard Hargrave, the CO of the South Coast Battle Group and was originally published in the November/ December 1998 issue of R/C Combat News, the official newsletter of the SCBG.

Author's Note: no attempt is made in this article to prove any of it mathematically. No formulas are provided to confuse the issue or the author. The author prefers less abstract explanations with lots of pictures.

THE PROBLEM

Many of our models exibit a varity of symtoms indicating some degree of instability. This varies from the barely noticable to outright thrashing that would beat to death any humans on a real ship like that. Not only can it look silly, but more importantly, it's a potential safety problem because of cannon "elevation" during the moments of roll-over. So is there one off-the-shelf solution to this problem? To some degree, yes. There are formulas and rules-of-thumb all over the place - mostly about real ships - not too much about models. And absolutely nothing but speculation when it comes to R/C Combat models. R/C Combat models are unique in the ship modelling world because most of their ballast is functional and bulky, unlike the little slabs of lead that can be neatly tucked into the "perfect", lowest places on a non-combat hull. So we have two problems: 1) how to stabilise a model's hull in general and 2) how to stabilise a hull full of heavy, tall bottles, gun systems, batteries and radio box(es). The first step towards solving this problem is getting some insight on what actually happens to a hull (of any size) when it heels over.



met·a·cen·ter (met′ə sen′tər), *n. Naval Archit.* the intersection between two vertical lines, one through the center of buoyancy of a hull in equilibrium, the other through the center of buoyancy when the hull is inclined slightly to one side or toward one end: the distance of this intersection above the center of gravity is an indication of the initial stability of the hull. Also, *esp. Brit.,* met′a·cen′tre. [< F *métacentre.* See -META, CENTER] —met′a·cen′tric, *adj.* —met·a·cen·tric·i·ty (met′ə sen tris′i tē), *n.*

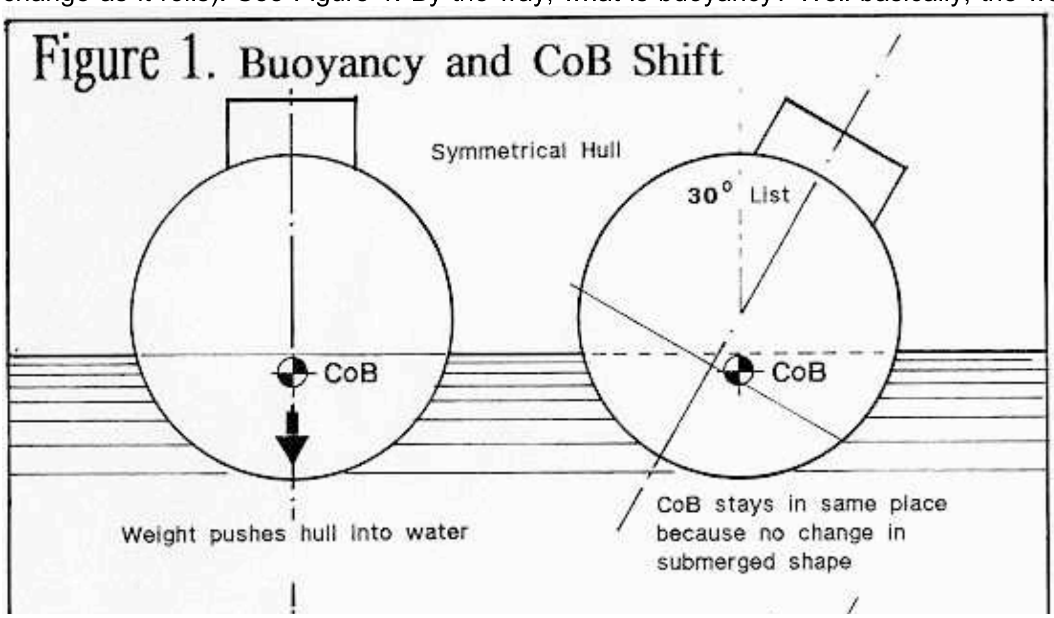
M, Metacenter of a boat; G, Center of gravity; B, Center of buoyancy; B′, Center of buoyancy when boat is displaced

met′acen′tric height′, *Naval Archit.* the distance between the center of gravity and the metacenter of a floating body, as of a vessel.

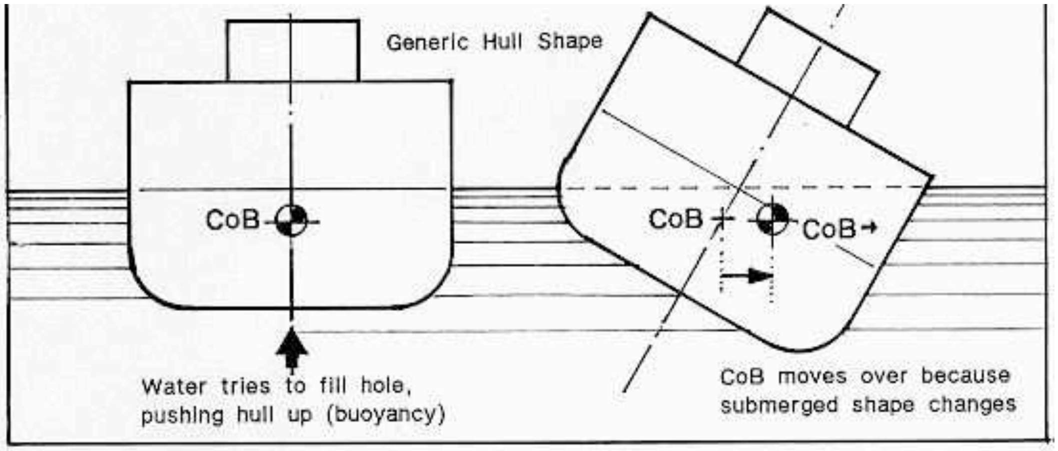
ini′tial stabil′ity, *Naval Archit.* the resistance of a vessel to heeling. Also called **metacentric stability.**

THE DREADED EXPLANATION

All hulls have a Center of Buoyancy and a Center of Gravity (C/G). The CoB is mainly related to the hull shape, whereas the C/G is related to where the weight is placed in the hull. The higher the C/G is above the CoB, the less stable the hull. No matter how you move the hull, the C/G is always in the same place on the hull. However, the CoB moves when the the hull rolls over because the hull shape is not symmetrical (a floating log or round tube is the exception because it is symmetrical so its underwater shape does not change as it rolls). See Figure 1. By the way, what is buoyancy? Well basically, the weight of your model hull is pushing a hole into the water (displacing it, hence displacement) and gravity is screaming at the water to fill it back up again. So the water's weight is pushing in from the sides and up from the bottom, trying for all the world to pop your boat out of the water like a nasty zit. There's more to it that that, but hey, this is only a newsletter.

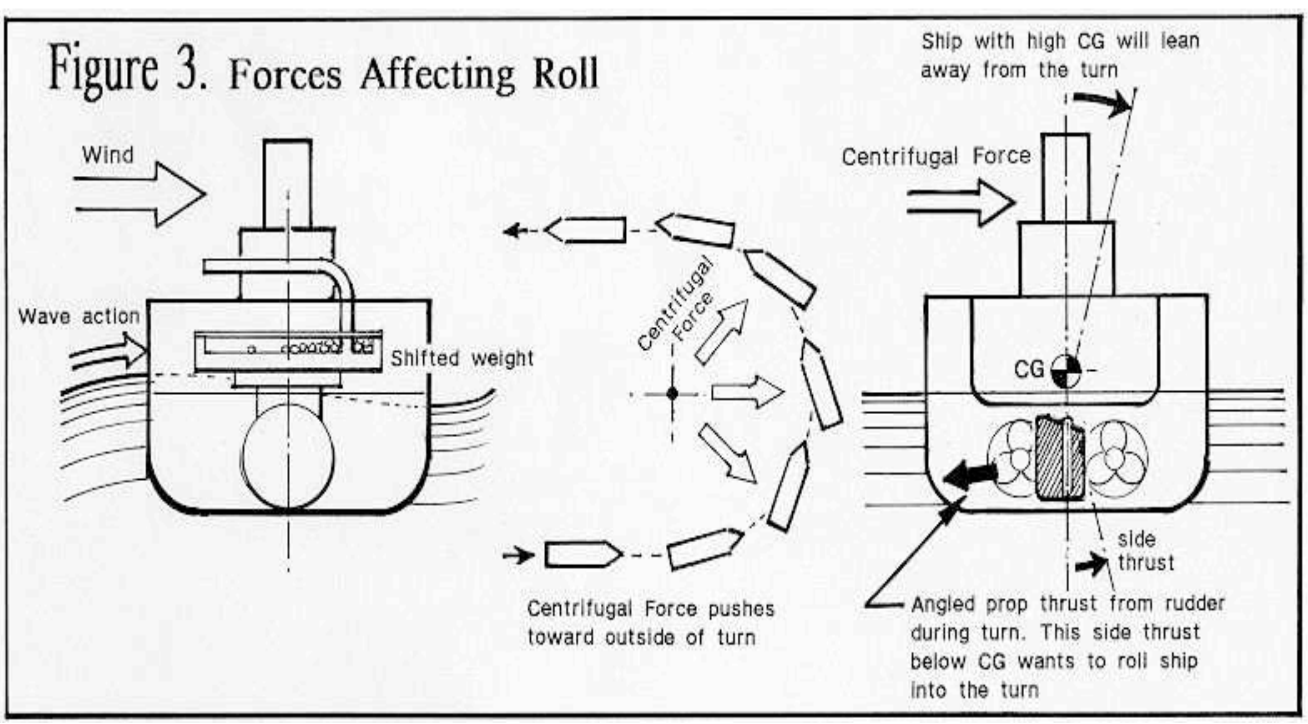


Okay, back to



confusing the issue some more. A ship's hull has a point called the Metacenter (M) and measurement called the Metacentric height... (GM) that is used to define the relative stability of a hull. See Figure 2. Fig. 2 is right out of the big Random House Dictionary of the English Language, 1966, Unabridged. I was really surprised to see a diagram in there, too. Take a minute and look up "metacenter" in whatever you've got at home. As you can see, the CoB moves away from the C/G when the hull tilts over. This is the main reason that the hull will right itself: The CoB is the center point of the upward force floating your boat. As long as this point is further away from the center than the C/G, the hull will right itself. Generally speaking, The CoB will shift less with narrow, round bilge hulls than it will with wide, flat bottomed hulls. The CoB shift in a wide flat bottomed hull can compensate for a much higher center of gravity - that's why big battleship models are generally more stable than little CLs or DDs. As long as the C/G stays between the Hull centerline and the CoB, gravity and the upward force at the new CoB will cause it to right itself when the force(s) causing it to roll subside.

Forces that cause a hull to roll are 1) Wave Action, 2) Centrifugal Force while turning, 3) Temporary weight shift due to rotation of unbalanced turret, 4) Weight changes due to depletion of ammo and gas and 5) The wind, to some degree. There's also prop and rudder torque, if you want to get picky. Suffice it to say, when some force wants to roll your hull over, you want the hull to A) Resist and B) to come back upright without delay. Duh. See Figure 3.



A hull will capsize when the C/G moves further out towards the low beam than does the CoB. See Figure 4.

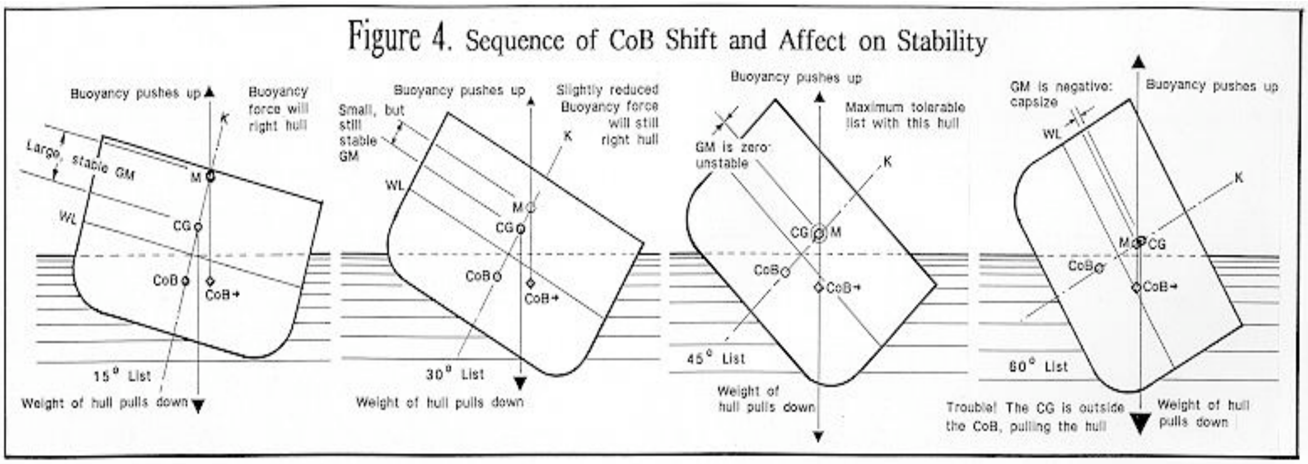


Figure 4. Sequence of CoB Shift and Affect on Stability

Once a hull is able to sit upright in the water and resist forces that want to heel it over, another problem may come up: oscillation, or the "pendulum" effect. The hull gets pushed over, the shifted CoB pushes it back too far, causing it to start rocking back and forth like one of those inflatable punching bags kids have/had (Rock'em Sock'em?). Damping this effect is important unless you like your model to rock like a cradle. This happens when the C/G is extremely low and all the mass is on the centerline and the beam is small compared to the draught and there is nothing on the submerged outer hull to help brake this motion.

SOLVING THESE PROBLEMS

Ironically, the answer to some of these problems will seem contrary to common sense, but trust me, I'm old.

- Obviously, get all the weight as low as possible in the hull. This includes your construction techniques, as well as the placement of your equipment.
- Building a strong frame is a given, but starting with the deck, build LIGHT. 1/8" plywood decks are convenient, but on smaller models, they are the beginning of top-heavyness. Consider using 1/16" on cruisers and 1/32" on Destroyers.
- Ultra lightwieght superstructure is a bit of a pain, but any mass up there is potentially destablising. Besides reducing highly placed wieght, whatever you save by building light can be put back where you need it to increase stability. My personal rule is to never use plywood, hardwood or plastic in the superstructure. This may mean more repair after a battle, but stability is mandatory for a stable, effective gun platform.
- Believe it or not, paint is heavy. Particularly the sandable primers. Although it hardly matters on a battleship, too much paint on a DD's superstructure can contribute to a problem. By the way, clear paints are the lightest.
- Once the ship sits upright in the water, tip it over 30 and watch it right itself. It should come back quickly with little or no rocking (oscillation). If it rocks more than twice, you need to dampen that effect. Remember all that weight you saved in construction? Well now you can use a small amount of that to dampen the oscillation. see Figure 5.
- On smaller models its not the best idea to hang any heavy equipment from the underside of the deck. This transfers the weight to the deck which may flex while the model is heeled over causing the weight to shift to the low beam side, worsening the list.
- Last, but not by any means least, make sure everything is BOLTED DOWN, as in secure, fixed, etc.. Anything that can shift, will. When this happens, the C/G moves and upsets the stability you have worked so hard to achieve.

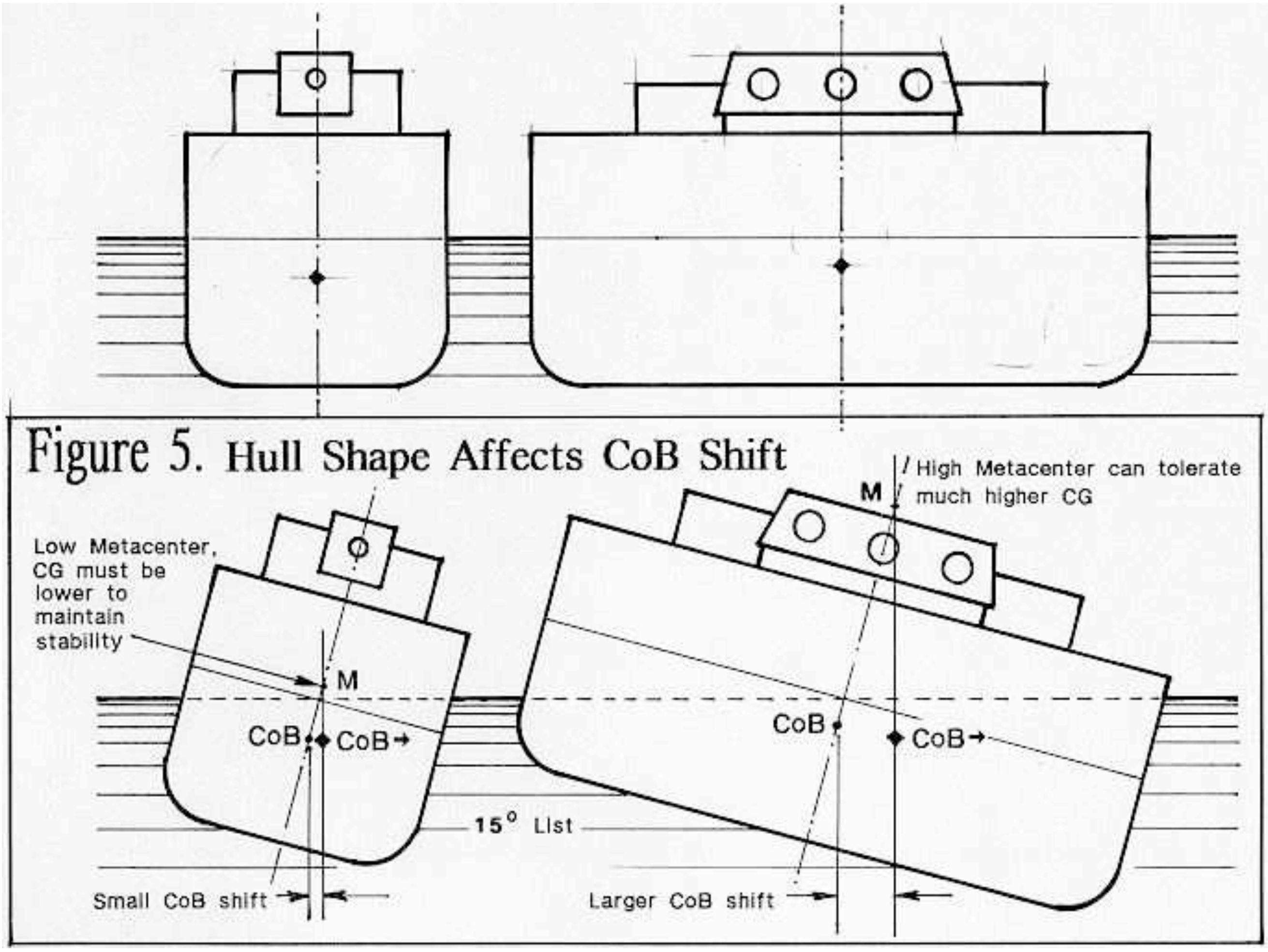
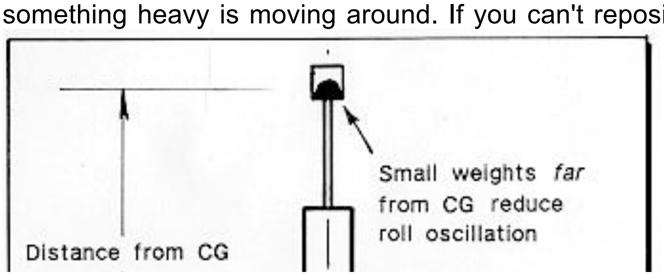


Figure 5. Hull Shape Affects CoB Shift

Have I missed anything? Sure I have. Hulls pitch fore and aft as well as side to side. That's a bit easier to deal with and is not as much of a problem for us since our weight is rarely concentrated in the middle (lengthwise).

Bilge Keels are used to dampen (slow down) side to side oscillation by friction with the water. These are not too effective on our models because of their small size. They are however, an excellent place to add more of that weight you saved! Ron K. and I stabilized his LeTerrible DD by shaving 3 ounces off the top and put it back on the bilge keels with metal-filled epoxy. See Fig. 5. Again.

Most of us don't experience prop torque problems because we're multi-shafted, but rudder torque is another story. A couple of our smaller vessels exhibit this problem: every time they turn the rudder the ship rolls into the turn (way too much) and then thrashes back the other way so much that a roll oscillation is started. See Figure 6. In conclusion, model ship stability is not a result of only one factor, but several: 1) C/G height, 2) CoB location/shift, 3) Hull shape and 4) Shifting weight. No matter how the the components are arranged in your ship, it cannot capsize as long as the C/G does not cross over the CoB when the the model heels over. If your model wants to roll over, then your C/G is too high for that particular hull, or something heavy is moving around. If you can't reposition your equipment in the hull, then you need to reduce topweight (superstructure, deck, etc.) and put that weight back on in the hull bottom - that's why the rules allow a lead strip to be attached to the outside bottom hull of small vessels. In some E-mail I've read there seems to be some confusion about centering or spreading the weight to the sides. Both techniques have their advantages: centered for vertical stability and wide for roll damping. As you can



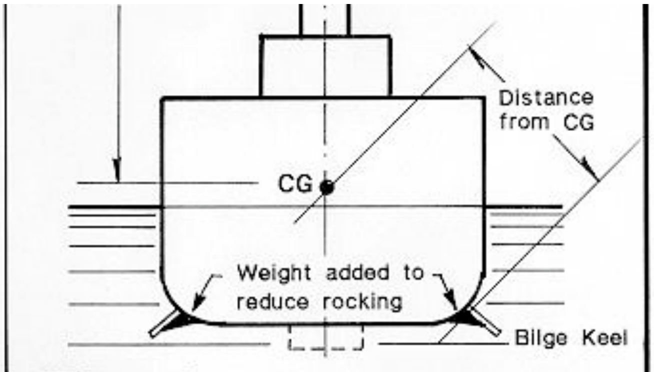


Figure 6. Using Inertial Resistance to Dampen Roll Oscillation

see in Fig.6, centered weight in combination with small, isolated weights as far as possible from the hull's C/G seems to be the best all around solution.