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The purpose of this briefing is to provide the audience with a brief introduction to the range of high speed hull forms that are currently in a naval architect’s tool box. I have assumed that audience is composed of persons who are considering becoming involved with high speed ships in one manner or another – either as future owners, or perhaps builders – and are trying to become familiar with the relative strengths of weaknesses of the various concepts.
In brief, the message behind this presentation is that there are a variety of hull forms available, and that each has its own strengths and weaknesses, each has its own niche. There is no one hull form that is best for all applications, but instead it is helpful to understand what each concept brings to the table, and what each concept’s limitations are.
The problem the naval architect attempts to solve is to maximize these five parameters. I will use these five parameters in characterizing the various hull concepts.

We should note, however, that…
Rather like the old canard says, this balancing act is not easy, and may even be impossible.
Since this presentation is about high speed ships, let me start with an introductory remark about speed and power.
What is Fast? Unfortunately, the answer depends upon size. A fast 100-foot boat may depend quite a different hull form solution from a fast 1000-foot boat. It is important to begin by understanding the relationship between speed and size.
This boat is fast
This boat is fast

This boat is fast…
This boat is slow…
Is this boat slow?

What about this one? In absolute terms this boat is faster than the kayak. It’s probably faster than some JetSkis and Bayliners, no matter what their owners may claim in the bar.
The question really is: What’s the difference between 20 knots and 20 knots?

And the Naval Architect’s answer is: Froude Number.
Froude Number is a trick for combining speed and size. In terms of Froude Number these two boats are just about equal…
In terms of Froude Number these two boats are just about equal.
Froude Number

- Froude Number
  - Speed divided by Size
    - “size” can be length, displacement, or many other things

- \( F_{n_L} = \frac{V}{gL^{0.5}} \) most common in naval architecture
- \( F_{n_V} = \frac{V}{g(\nabla)^{0.333})^{0.5}} \) used by IMO HSC

For those who really want to know: This is the formula for Froude Number. It’s important to realize that there are a lot of different “types” of Froude Number. I have shown two of them. When somebody quotes a Froude Number to you, you can look really “in the know” by asking what type it was. Length-based, volume-based, or what?

But this detail is unimportant to what we are talking about here. What we are talking about here is that Froude Number allows us to combine the effects of speed and size, so that when we talk about “fast” ships we mean either 20-knot 60 footers or 60-knot thousand-footers.
High Speed means More Power. That’s probably obvious. But let’s look at a graph…
This is a graph of the power required, per tonne of displacement, for a range of Froude number. You can clearly see that as the ships go faster the power demand rises dramatically.

For the record, those Washington State Ferries that I called “slow” are right about here, at the lowest group of spots. That 60-knot motor yacht is here, Fn=2.5, 60 hp per tonne.
Conversely, we can see in the next graph that it’s easier to go fast if the boat is small…
This graph plots the same ships, but this time we’re comparing their speed (in Froude Number) with their size, in passenger count. The Washington State ferries carry some 1000-2500 passengers. The 40-50-60 knot ship are all in the less-than 500 passenger category.
But the point of this is hull forms. This was our graph of power versus speed. Let’s look at what hull form these ships are…
Here you begin to see the niches for each of the hull types. The catamarans were invented in order to get speeds up higher than the monohull range. SESs and Hydrofoils were further invented to reduce the power demand at the highest speeds. In the case of this hydrofoil, the issue was ride quality, and the power demand is actually slightly worse….But let’s go look at some ships:
These are the six hull form types I would like to talk about.
The most common of course is the monohull. They have been around for 
millenia, they are extremely efficient versatile hulls.
Some of the highest performance monohulls are painted grey. The selection of the monohull form by these customers is not due to a lack of money, but is due to the extreme versatility and efficiency of this form, up to a Froude number of about 1.
Planing Monohulls

- Patrol Boats / Recreational Craft
- L:B approx 3:1
- Short sea routes
- to 50 knots
- Generally Small

To get to higher Froude numbers we start trying to get the hull out of the water, and the first step is a planing hull. These are found commonly in Patrol boats and recreational craft.
The most extreme planing hull I am familiar with is Destriero….
This is a 60-knot 220 foot private yacht. She has an unrefueled range of more than 3000 nautical miles, and has crossed the Atlantic ocean unrefueled in about 60 hours.
Destriero sails at an ambitious Froude number of 2.5, but she carries very little payload. A real commercial payload-carrying ship is the Italian Jupiter monohull, which sails at a Froude Number of 2.0, or 44 knots.
Here’s the Jupiter…
Designers try other methods to get monohulls to go fast. An alternative to planing is to use extreme slenderness – very narrow beam.

This usually results in an unstable ship, so some sort of outrigger has to be used to get stability. The result is the trimaran....
This trimaran holds the record for fastest around the world trip, having completed an equatorial circumnavigation in less than 80 days.
Here’s another outrigger stabilized monohull, intended as a container ship.
The same push to slenderness gives rise to the catamaran. The catamaran uses a very slender hull to get low drag, but it overcomes the stability problem by putting two of these hulls side by side.
Catamarans

- Two Slender Hulls
- Displacement Ships
- Lots of Room - Well suited for low density cargoes
- Ferries

The result is a large spacious cross deck, which can be very useful for space-hungry cargoes, such as human beings. For a denser cargo trade, such as, oh, say, oil tankers, we don’t see any catamarans, because their spaciousness is not useful with such a dense payload, and indeed their somewhat more complex structure becomes a penalty, not a benefit.

But for ferries they have fitted very well, and we have many impressive examples…. 
Austal 86m Catamaran

This is a big Austal cat, and it depicts a more conventional sort of catamaran.
Here’s a few pictures of another fairly conventional cat, built in Canada.
PacifiCat (BC Ferries)
I have included a few shots of the interiors of these two cats, to give some feeling to the statement that they are spacious.
PacifiCat (BC Ferries)
Austal 86m Catamaran

Midships 'Poolbar Restaurant' on the main passenger deck.
Catamarans have encountered some difficulties, and particularly in the early days there were some issues with ride quality. In an attempt to improve the ride, the Australian naval architect Phil Hercus, who is still in collaboration with Matt Nichols and John Duclos here, invented the wave piercing hull form. This hull form concept uses a narrow protruding bow to pierce or knife through the waves rather than rising up over each one. Let’s look…
Here you can see the wave piercing bows, which are these two with the stripes. This central bow that you can see does not actually touch the water, as we can see in this next picture…
You see here the two wave piercing bows, and the center structure is well clear of the water.
Now, those cats I just described are in the speed range of Froude Number 2.0. There are cats that go faster…
But to get up to these speeds we have to make some hull form changes. In particular, these two boats, both at about 50 knots, have now married the planing hull form with the catamaran.
Here’s a picture, and perhaps you can see by this wave and spray pattern how much this looks like the type of behavior you’d see in any other planing boat, such as a ski boat or whatever. With these planing catamarans the architect is able to incrementally increase the speed, but of course always at some penalty in both power and comfort level.
Another way to make a faster catamaran is to lift the whole boat out of the water, using underwater hydrofoils. This is a fairly old concept, but there aren’t many real examples in the water.
This foil assisted Cat was built in Sweden a decade or two ago, and is no longer in service.
This picture depicts sort of what these underwater foils look like. This is not, in fact, the foil under the catamaran on the previous slide, but in general size and configuration it’s not far different.
That brings us to traditional hydrofoils, which is to say monohull hydrofoils.

These ships are, without doubt, the most comfortable, smoothest ride, of any of the fat ship concepts.

Unfortunately they are also the most expensive by far.
Hydrofoils

- NATO Patrol Craft project
- approx 150t
- approx 40 m
- 50 knots
- No large commercial units

Hydrofoil development. Was. Like so much else, originally military drive.
This was the USN hydrofoil patrol craft, of which six were built. They have all been retired by now.
The patrol craft were built by Boeing, who then developed the ferry product line known as the Boeing JetFoil. 45 knots and 250 passengers, were unparalleled ride quality.
Boeing JetFoil

- 2x to 3x times the price of a Catamaran

I believe they are running 13 to 17 Million dollars today.
The next class of vessel are the air-cushion catamarans or Surface Effect Ships. In this type of vessel a cushion of pressurized air is used to lift the boat above the water. The result is a reduction in drag, and thus a fast and efficient hull form. The drawback is the mechanical complexity.
Surface Effect Ship

- Air Cushion Catamaran
  - Air Bubble (like a hovercraft) between the hulls of a catamaran.
  - Less power for high speed
  - Less Power = Less wake wash

Here we see again a tradeoff between speed-power performance, versus other concerns such as simplicity and low cost.
Here is one of the better looking (in my opinion) SES of the world, built in Norway. About 400 passengers, with a 42 knots service speed.
There are also American SES designs, of which this is one. This is a 149 passenger type vessel, which I believe has no been built and placed in service.
Of course, the landmark SES project was the US Navy program in the 1970s, and I can’t resist showing just one or two pictures from this effort…
The project was an R&D effort, and it built these two 80-foot test craft. The uppermost of these boats exceeded 100 mph.
Continuing on with the air cushion theme we come to the hovercraft. The ACV or Air Cushion Vehicle is a fully skirted craft, which does not have the catamaran side hulls of the SES, but is in fact more like an Air hockey puck. As a result of it’s total air cushion, it is an amphibious craft.
ACV’s tend to be noisy, therefore a bit uncomfortable, and mechanically complex, but they do have unmistakably unique capabilities…
Such as the ability to fly up over the beach…

While it’s true that very few PVA members need to transport Army tanks, it is worth remembering that large hovercraft successfully served on the English Channel for over 25 years. They have since been replaced by catamarans, since the route really didn’t need their amphibious capability.

I have seen some written materials which propose amphibious hovercraft for airport-to-airport service across San Francisco Bay.
Well, as long as we’re flying above the ground, let’s add the Wing in Ground Effect machine.

There aren’t any of these in ferry service, but they may have a niche, and they are a nice futuristic point to end on.
“Strizh”-class WIG

About 100 knots
Froude Number = 14

Here’s a small passenger ground effect machine, shown flying at it’s full height.
Large Russian WIG (military)

And here’s one of the ones that started it all, flying in the late 1970s

I don’t expect too many of these to be docked in Dick Purinton’s neighborhood, but at least now you can claim to have seen a picture of one..
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