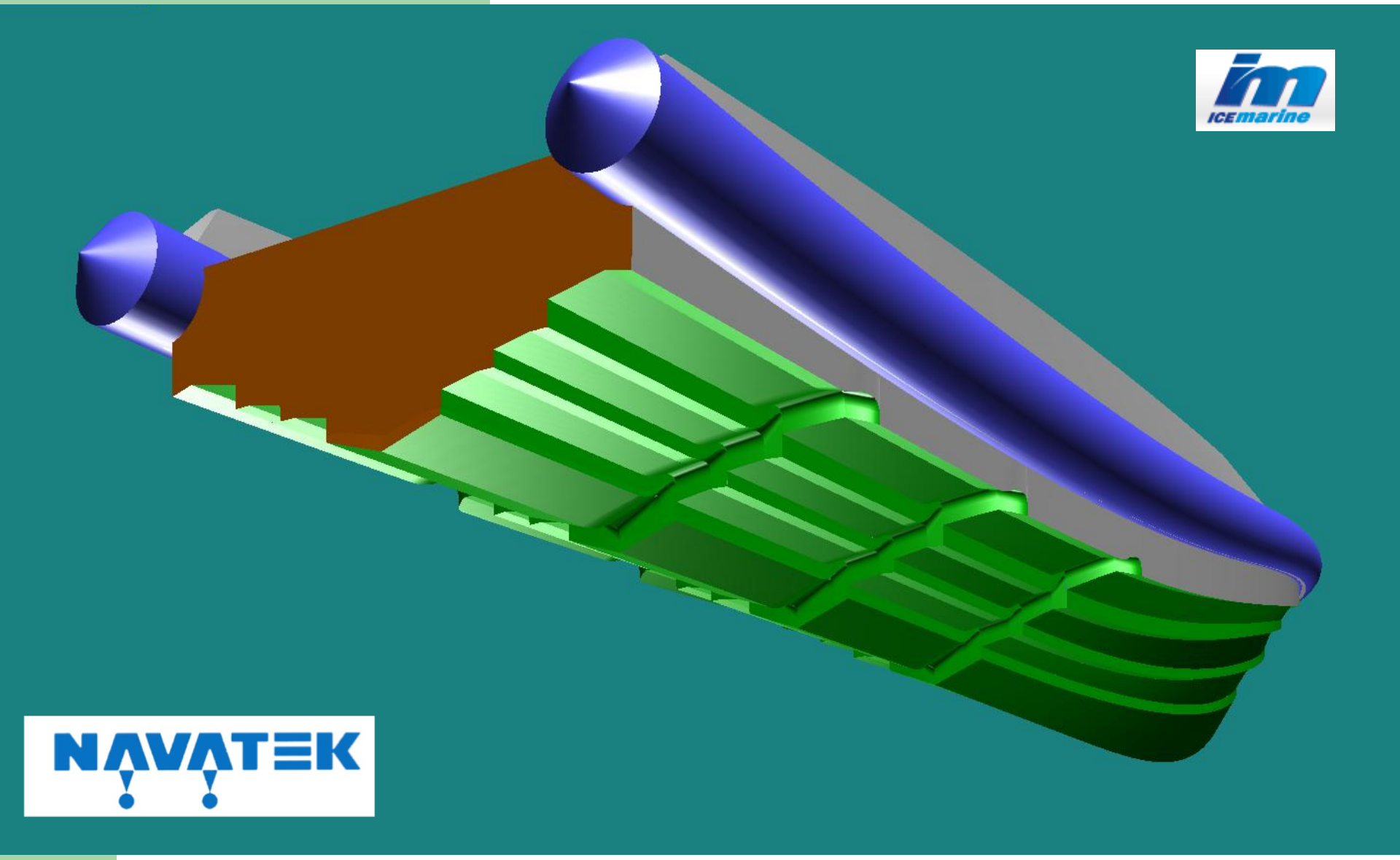
Notes on Stepped Hulls

What is a stepped hull?

- When referring to a ‘stepped hull’, the accepted, default meaning is a hull having one or more transverse steps.
- Some will talk about longitudinal steps, which have a similarity to spray rails.
- In this presentation we are referring to transverse steps, only.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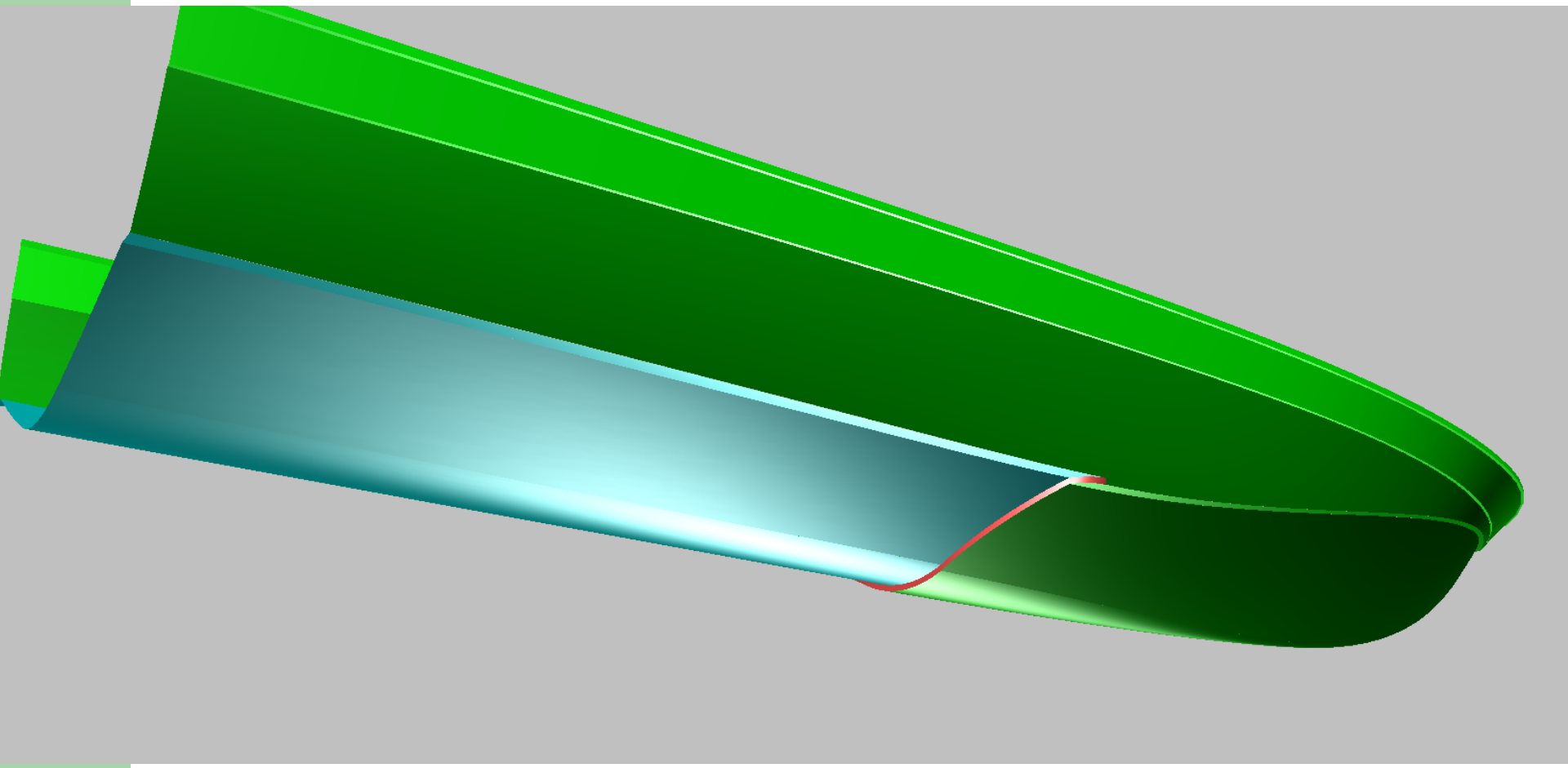
Basic Single Step



Advantages – If correctly designed!

- Drag reduction of 8% - 12% when planing
- Pitch reduction and improved pitch control when running in a seaway
- Increased resistance to Porpoising

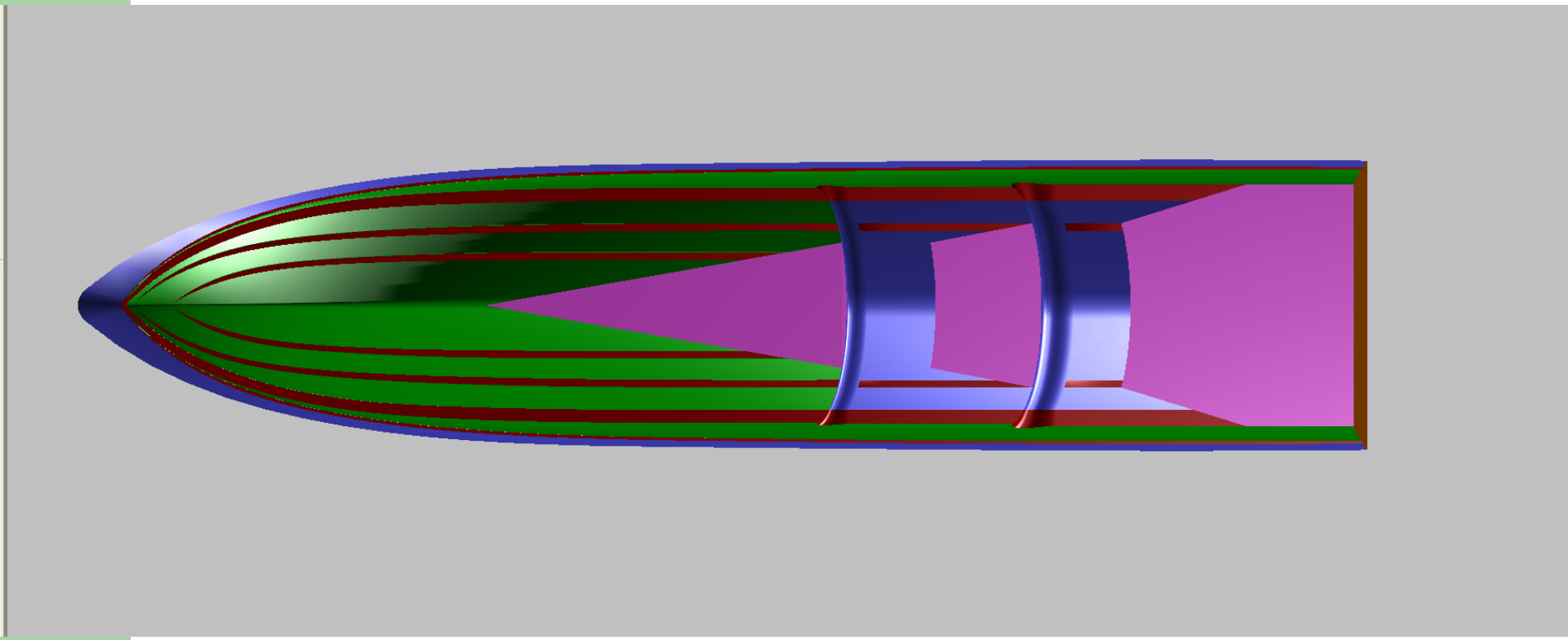
Disadvantages

- Takes more design effort to get it right.
- Cannot normally use Waterjets.
- Directional Stability can be a problem if care is not taken!
- Can sometimes be more difficult to achieve plane, but not always the case.
- More drag at displacement speeds.

Reasons Behind Speed Increase:

- Higher wetted aspect ratio of each individual surface improves lift per unit area – hence less wetted surface is needed, resulting in reduced friction drag.
- Aspect ratio is wetted beam divided by mean wetted length.

Wetted Areas:



Speed Range

- Above speed/length ratios of 5 – 6, or Fn ~ 1.5 – 1.75.
- Below this speed, steps are not much advantage for efficiency, but can still have trim control benefits.

Control in Pitch – Non-stepped:

- With non-stepped hull, pressure from wave lifts the bow as the pressure runs aft towards the CG.
- By the time it has reached the CG the upward momentum in the bow is well established and craft leaves the water bow high.
- This means the craft is pitched to a high angle before the pressure starts to lift the aft end.
- Hull will often leave the water before falling back in on its transom, which then lifts the stern and pitches the bow down.

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Control in Pitch – Stepped:

- With a stepped hull the wave pressure skips rapidly from one surface to the next.
- On contact, the bow starts to rise but then the lift input stops as the wave leaves the first step.
- Then the wave contacts the next surface aft, which is close to the CG and, therefore, lifts the hull bodily without adding any more pitch change.
- Again the pressure leaves this surface and skips to the next which is likely to be aft of the CG and so lifts the stern.
- This system also gives the higher resistance to Porpoising.

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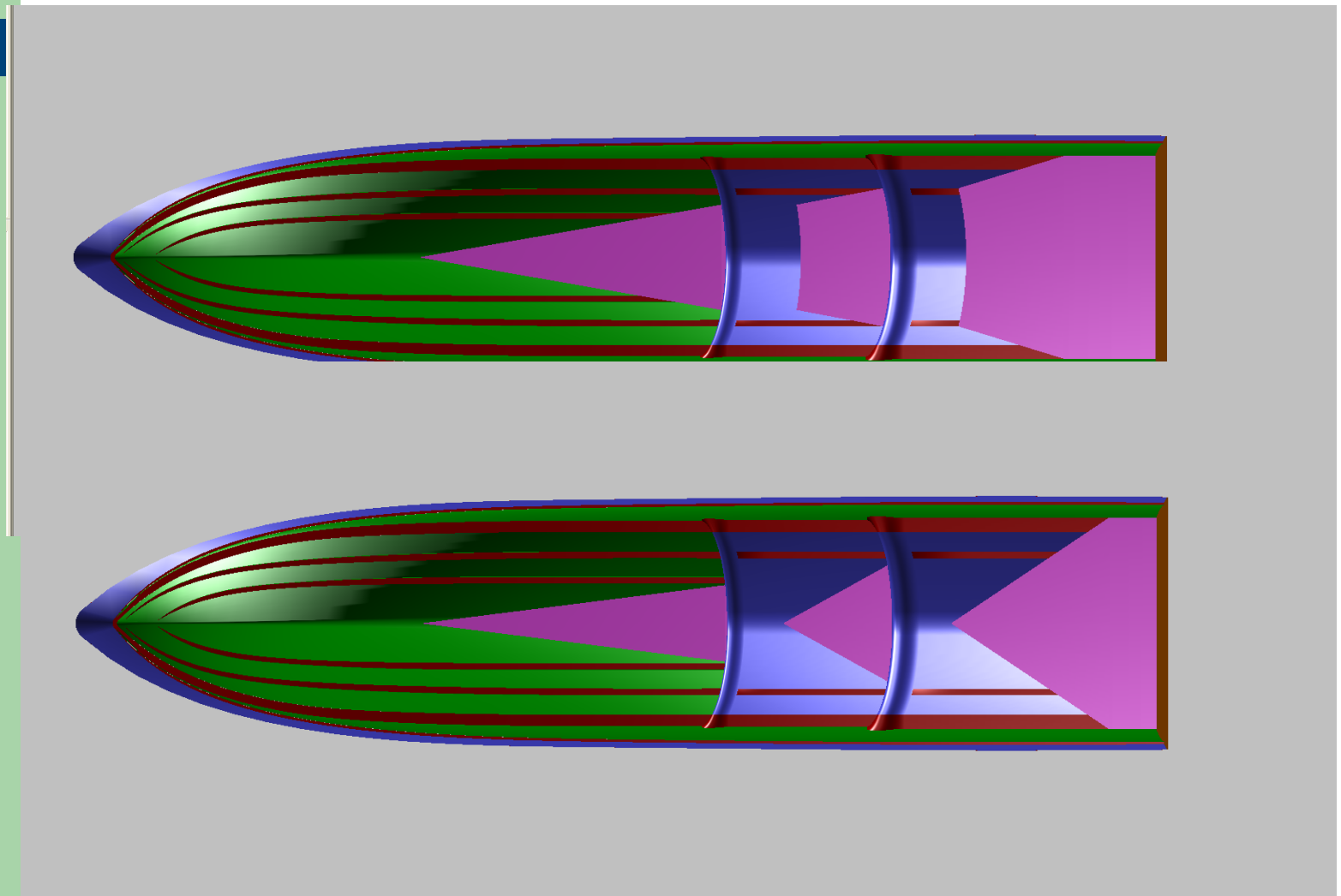
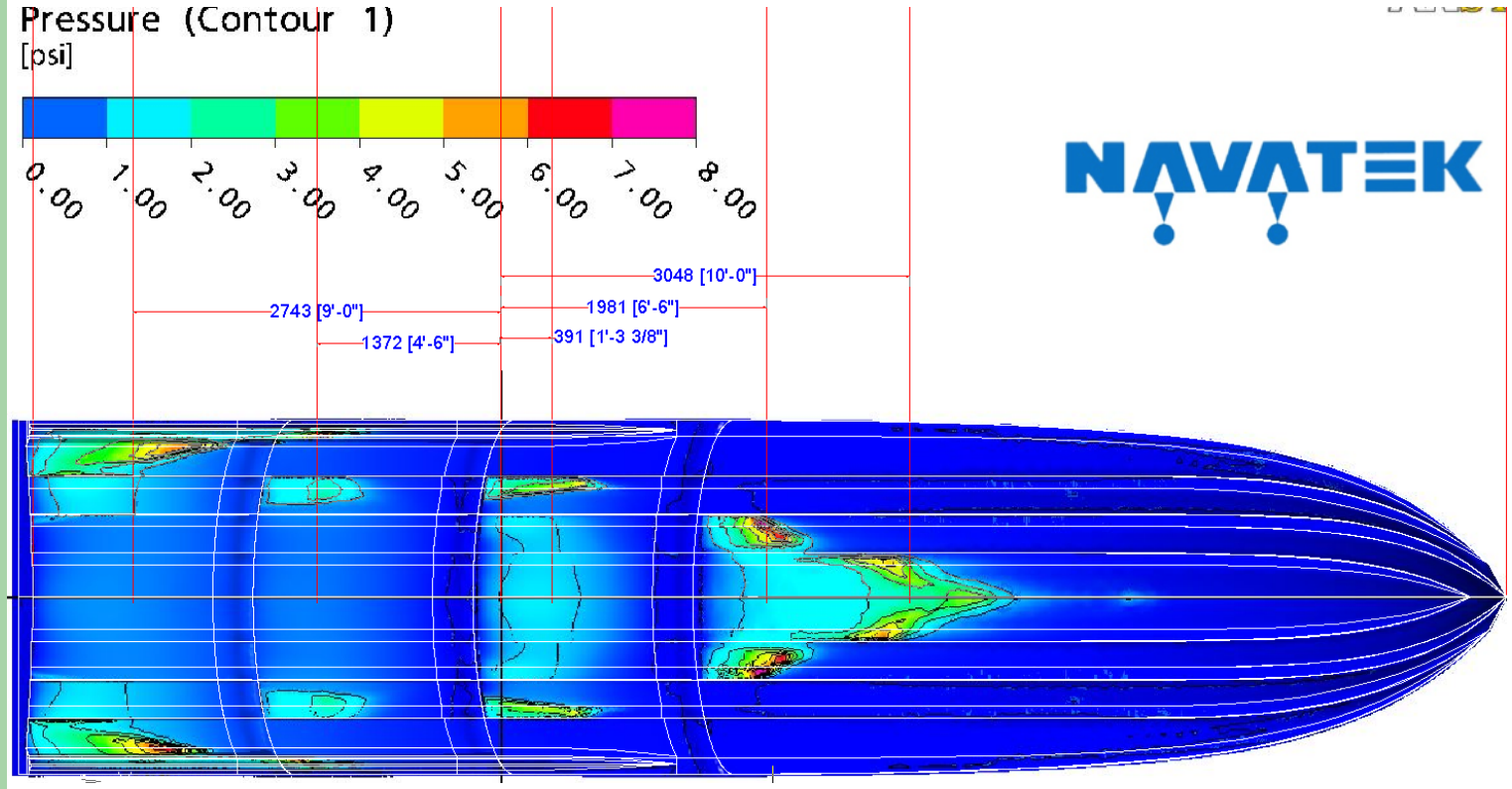
Incidentally: Wetted Areas – Right and Wrong!



Wetted Areas:



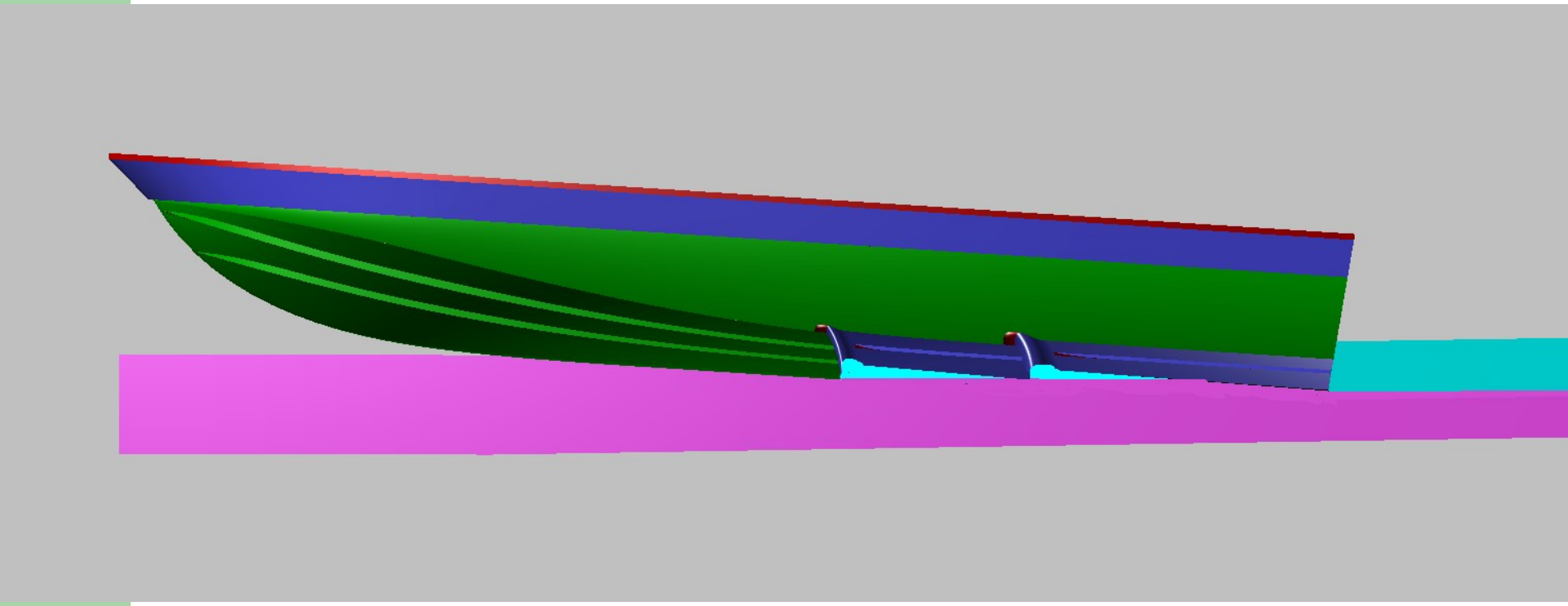
Speed and Handling:

- The further aft and deeper the steps, the more the drag reduction – but the worse the handling is likely to be!
- This is because the deeper steps allow a higher angle of attack – less friction drag – but the forward surface carries more load with the aft surfaces more shielded!

Step shielding:

- No drag on aft end but no location, either! Some lateral resistance is needed at the aft end.
- Generally light boats with an aft LCG can have steps positioned relatively far aft, while forward LCGs need more forward step positions.

Steps too deep!



Directional Stability:

- So, shielding of aft surfaces reduces drag, but the hole it creates reduces lateral location.
- The aft end needs side area in contact with the water to hold the craft straight. I.e. fin effect.
- Allowing the aft surface to be well in contact with the water by having the aft step not too deep and a reasonable distance forward, means that there is enough lateral area in contact with the water.

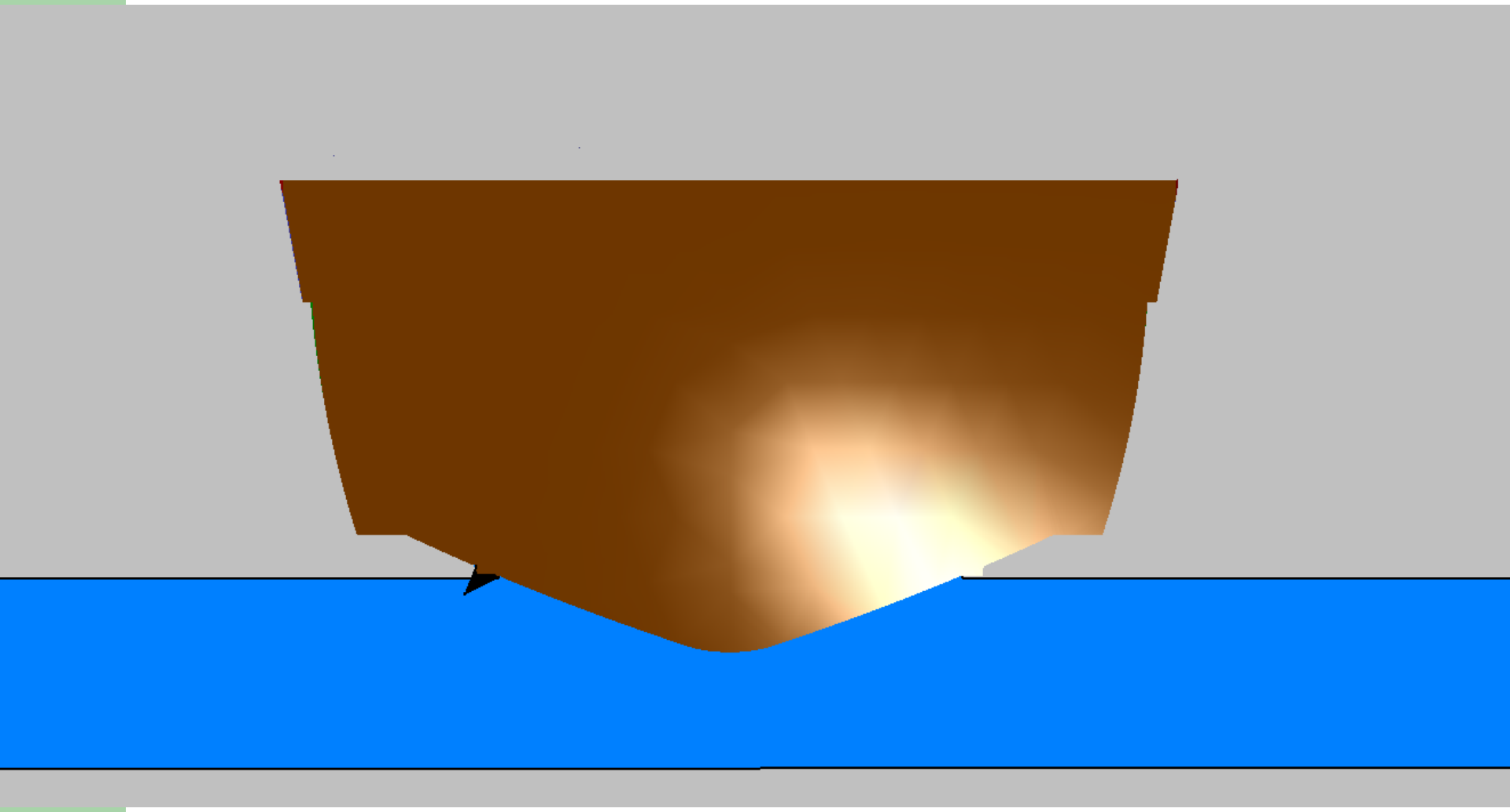
Roll Control:

- Chine rails important in roll.
- If chine is clear of surface at high speed, then an outer spray rail is needed instead.
- If craft rolls to one side and sticks it is usually a problem caused by hull shape; VCG or LCG.

Chine Walking:

- If craft chine walks it is trying to stabilise itself but there is too much or too little righting moment and/or too little damping.
- Phenomenon needs more research for prediction – particularly if hull is not model tested.
- Applies to non-stepped as well as stepped hulls.

Chine and rail mods:



Cures:

- Reduce height of VCG
- Increase/Adjust righting moment from chine or spray rails
- Often coupled with yaw, so improving directional stability is important – good ‘fin effect’ aft and no slop in steering!

Decisions:

- Calm water speed v rough water performance
- Like a non-stepped hull; the further aft the LCG the less the resistance
- The more forward the LCG the better the rough water ride
- But for each LCG position the ride and resistance are better than for the non-stepped hull

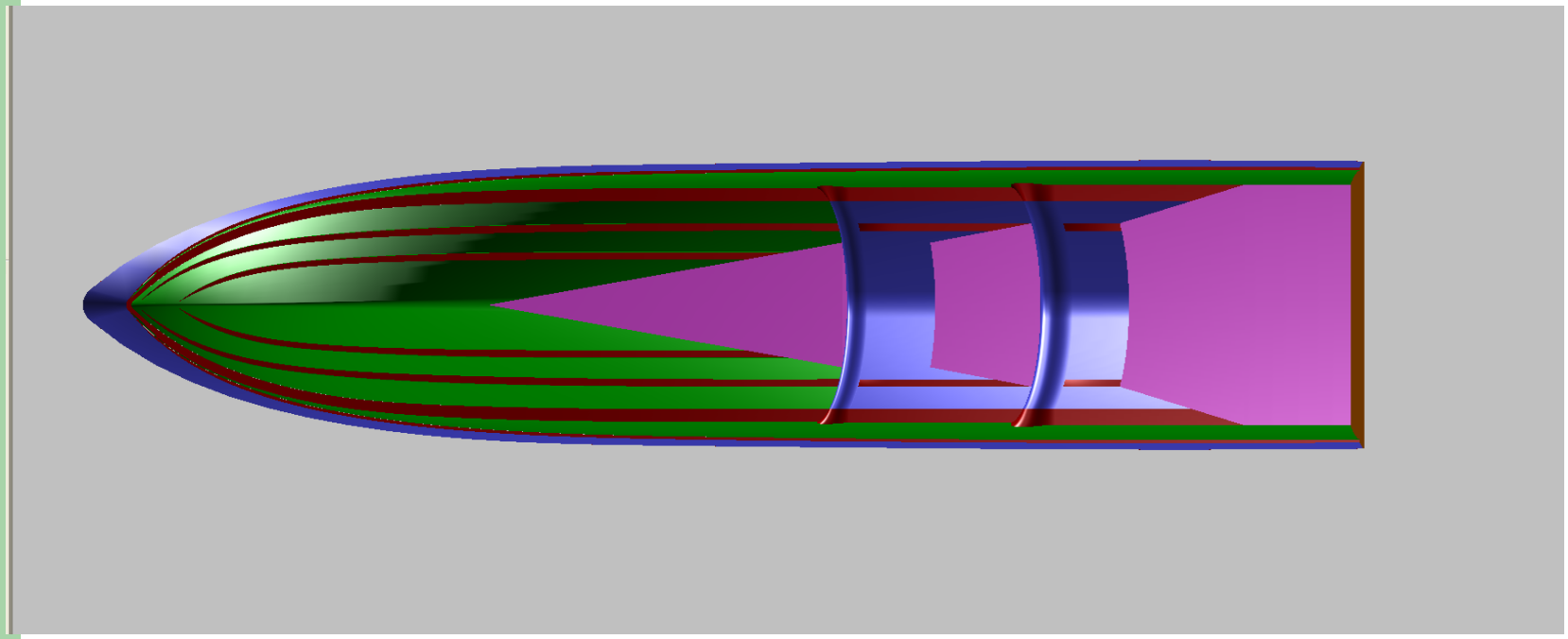
More Decisions:

- Number of steps
- Step longitudinal position
- Step Height
- Step shape in Plan View

Information Required:

- Weight and Hull Loading
- Speed, Deadrise, etc.
- Longitudinal Centre of Gravity

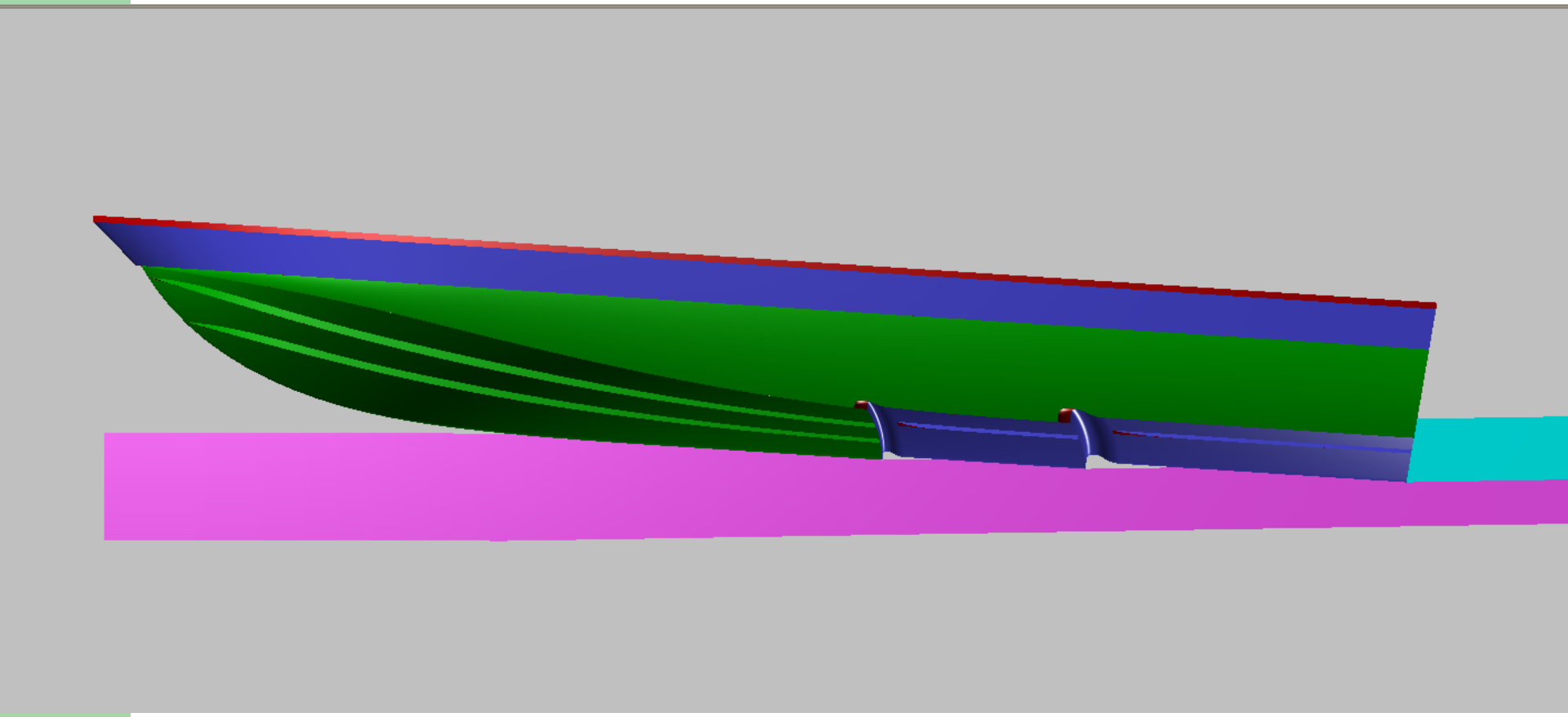
Step shape in Plan View - Ventilation



Lift & Drag Calculation:

- Modified Savitsky – Split between surfaces.
- How do you work out wetted lengths of surfaces (hence wetted areas)?

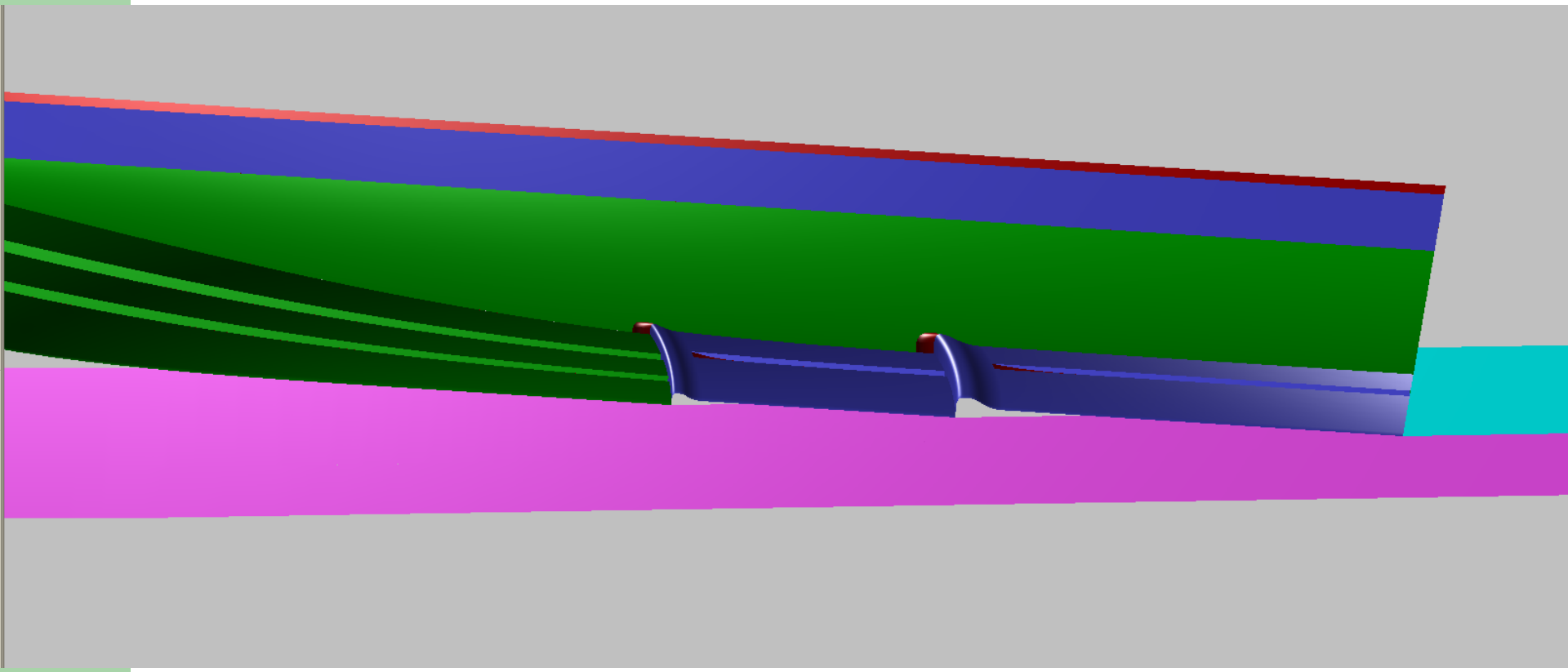
Wetted lengths:



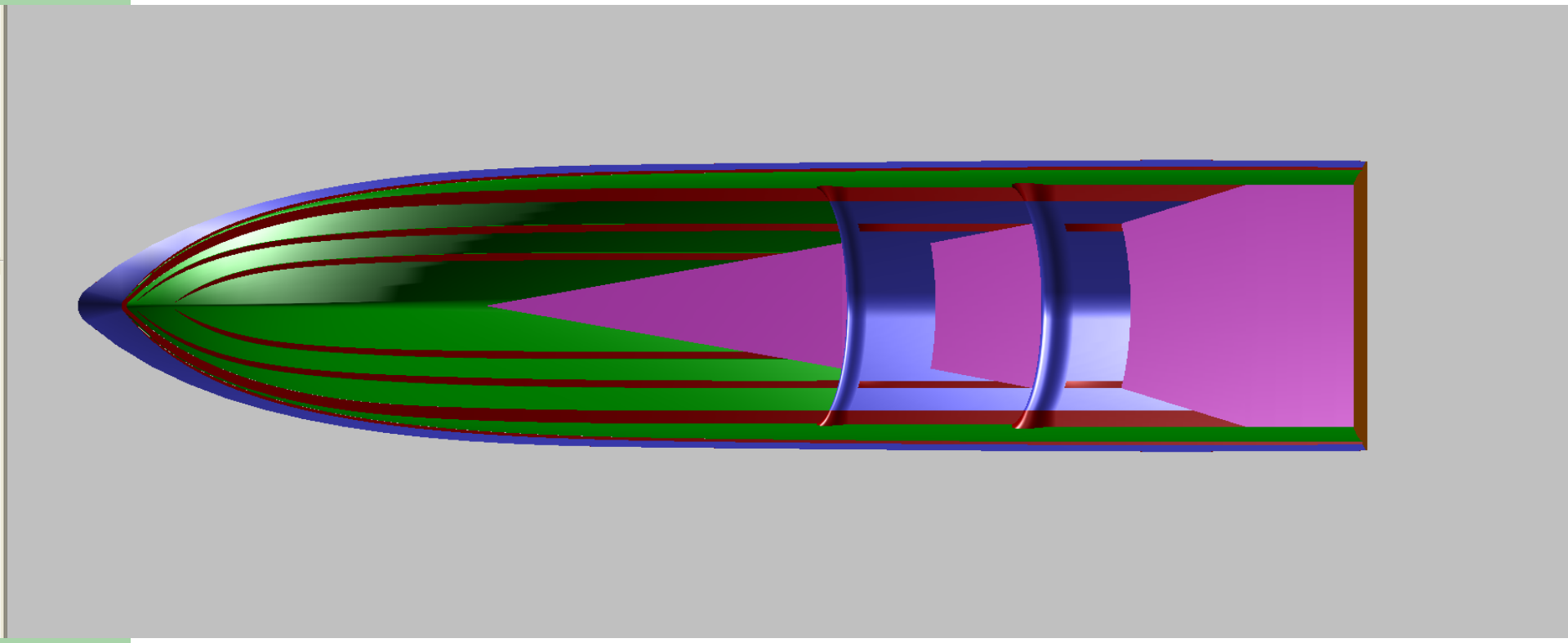
Path of streamlines aft of steps:

- Water is heavy stuff and does not like to move quickly.
- At lower planing speeds water can leave transom at the buttock line angle and then rise (Savitsky, Clement et al).
- At higher planing speeds solid water does not have time to move out of the way, so the hull just scrapes off the surface layer and throws it aside as spray.
- Thus the underlying solid water surface hardly moves.

Position of leading edge of wetted surface:



Gives this pattern:



Balance calculation (iterative):

- Amount of Lift, Drag and Centre of Pressure on each surface is needed in order to balance the boat.
- Also need aero lift, drag and CP, plus the same for appendages.
- Thrust and thrust line, too.
- Final lift resultant must be under the CG.
- Same as for non-stepped hull but more complicated!

Future:

- CFD is getting there but not reliable, yet, in most cases. Better at some speeds than others.
- I have been collaborating with Navatek in Hawaii applying their CFD expertise and my Savitsky method.
- We are getting closer to each other – Who is closest to right…?

Thank you!

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