# VPP Performance Predictions for Current and Two Proposed Navy-44 Designs

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INTRODUCTION:

VPP (velocity prediction program) analysis is used to predict the speed of sailing vessels in realistic conditions. VPP programs use hull, rig and appendage parameters of the boat to produce numerical predictions of several performance and speed-related features of the boat. For this study, VMG (velocity made good) upwind and downwind performance, pure boat speed, and resistance values are compared between the current Navy-44 and two proposed design configurations. Results showed that significant improvements in boat speed, VMG, and resistance can be achieved through modifications to the current hull form and appendages.

SETUP:

The VPP used for this study was developed by Chris Todter to improve the performance of boat designs for an American syndicate for the most recent America's Cup. With detailed input parameters, this VPP gives perhaps the most accurate assessment of boat performance available without actually building and testing a model or full-size boat. The program runs on an Excel spreadsheet, is easy to load and use, but requires a fast processor and a good deal of RAM to run efficiently. A second spreadsheet is required to download data.

PROCEDURE:

The first step for this study was to develop performance specifications for the existing Navy-44. IMS ratings sheets, phone calls, and a little legwork were required to gather the necessary data. Hull, keel, rudder, and rig parameters were adjusted to meet the current boat's specs. Roll moment was also adjusted to fit inclining experiment Navy-44 parameters (see "Navy 44 Inclining Experiment [7 AUG 2000] Discussion and Results", A.P. DeMeyer, 2000), and the crew weight was taken into account as well.

At this point, the VPP was run. This study focused on three wind speeds (6, 12, and 24 knots), but to achieve the largest amount of original data possible, all speeds were selected for the initial run. Results were then recorded on a separate spreadsheet for later analysis.

This process was followed again in successive runs involving single- or limited-parameter changes to the current design to gauge the performance changes of different modifications. Finally, two combinations of changes (labeled "Mid-line" and "Performance") were tested to determine if the combined modifications would have a beneficial effect on boat performance. Each time, the pertinent data (VMG, boat speed, wind angle, heel, and thrust) were recorded and placed in a separate spreadsheet to preserve the data for analysis.

The following table outlines the changes to the hull form and appendages during the study:

| CHARACTERISTIC | BOAT | VALUE |
|---|---|---|
| LOA: | All | 44 ft. |
| LWL: | current | 34.125 ft. |
| | mid-line | 38.5 ft. |
| | performance | 41 ft. |
| Displacement: | current | 28598 lb. |
| | mid-line | 25000 lb. |
| | performance | 23468 lb. |
| Canoe body depth: | current | 3 ft. |
| | mid-line | 2.5 ft. |
| | performance | 2.25 ft. |
| Canoe body volume: | current | 254.66 ft^3 |
| | mid-line | 230.19 ft^3 |
| | performance | 206.25 ft^3 |
| Type of keel: | current | current keel |
| | mid-line | Spring 2000* |
| | performance | Spring 2000* |
| Righting moment: | current | current value |
| | mid-line | 1.15*current value** |
| | performance | 1.15*current value** |

* The Spring 2000 keel design refers to a higher aspect ratio keel with an IMS bulb developed for the new Navy 44 (see "USNA 44-Foot Sloop Keel Re-Design Project", A.P. DeMeyer, 2000).

** This value is a result of the new keel's lower CG. This may be a conservative estimate, as any laminate changes are likely to lower the KG of the boat as well (in full load).

Data for the multiple runs was then analyzed and graphically represented in the second spreadsheet. Several polar plots directly compared true boat speed at given wind speeds. In addition, bar graphs of VMG comparisons and VMG improvements were created. Finally, a single resistance comparison graph was developed.

DISCUSSION:

The benefit of a VPP is that multiple runs of multiple configurations can be made without producing models. This is an enormously effective tool, as it allows a designer to make several changes to a hull form and optimize a shape without actually spending the money on models and towing tank time. Further testing in a towing tank then builds on VPP data, and a more limited amount of time and resources is used in the follow-on tests.

Common sense and training dictate that certain generalized changes in hull shape and appendages should change performance in given ways. What is never clear, however, is how those changes will interact. Furthermore, any given change to a hull or appendages invariably changes other aspects of the design. For example, changing the displacement of the boat will likely change the submerged volume, block coefficient, wetted surface area, and stability. For this reason, any changes in the boat's parameters needs to be analyzed, and a best estimate of other changes should be taken into account as well. There are inherent flaws in data of this nature, but not of the magnitude as to make the data unusable. Flaws are minimized by changing as few parameters as possible and documenting changes when made.

In general, lengthening the waterline will increase speed. This is due to the lower Froude numbers achieved in making wetted length longer. Other beneficial changes include general weight reduction, increased stability, changes to appendage shapes (and weight distributions), and changes to the hull shape. The current boat design is relatively heavy, and the underwater hull form includes a very round-bilged canoe body and a plain deep keel of low aspect ratio and high CG. Weight savings and hydrodynamic shaping of the hull can produce a less rounded bottom and higher aspect ratio keel with an IMS bulb. This should (and results proved *does*) produce a faster and more stable boat.

The two proposals (labeled "Mid-line" and "Performance") are a result of critical thinking about the two major programs tied to Navy sailing. The Varsity Offshore Sailing Team (VOST) would like to dramatically improve the speed and handling performance of the vessel. Hardly an unlikely suggestion, the VOST program would like to have fast boats for competition sailing (hence the performance proposal). The CSNTS program, on the other hand, relies on the ability of novice sailors to easily learn the systems and requires more safety features (hence the mid-line approach). Neither of the suggested hull forms is radical in design, and neither stretches safety limits for offshore sailing. In fact, both actually show measured improvement in stability calculations. And importantly, both designs fit within the requirement for overall length, draft, and the requirement to maintain the same sail plan and rigging.

## COMMENTS AND SUGGESTIONS FOR FURTHER STUDY:

The best way to achieve more accurate data would be to start with a whole new design. Given new offsets and a better idea of displacement and appendage locations and specifications, the input parameters would be more accurate, making data fit true design specs. Unfortunately, the time involved in developing new data is prohibitive.

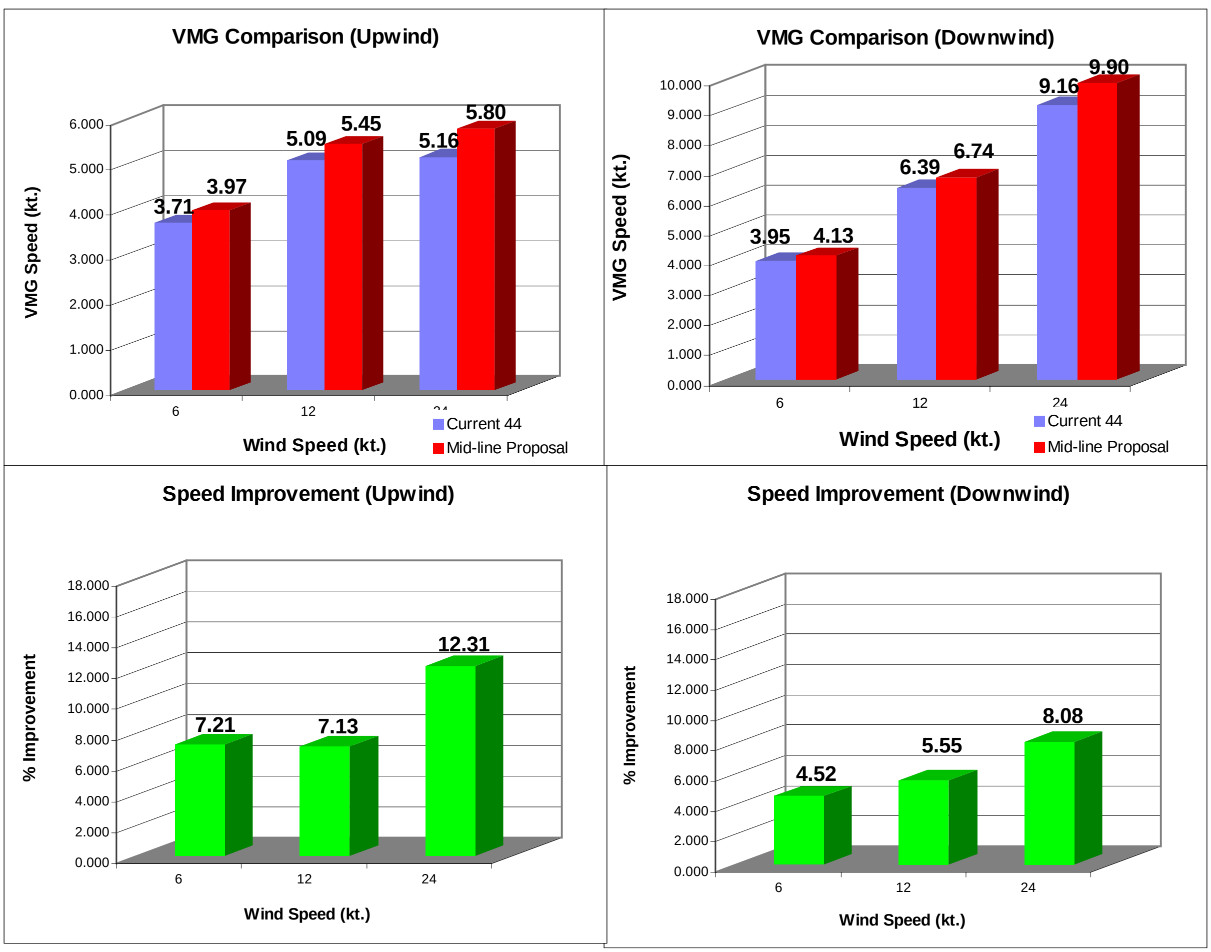
A good way to acquire more data, however, would be to simply change more parameters, and to do so in the same manner as has been done in this limited study. More parameters, perhaps changed in graded amounts, can quantify the potential performance benefits of given changes. This could be useful if curves were developed for optimizing the hull form, though the amount of runs necessary for finding the data would be mind-boggling.

Perhaps the best way to build on this data would be to design hull forms to fit the parameters used for these two proposed hulls, build models, and tow them. Likely, small differences between the computer model and tow tank tests would exist, but just as likely, the model tests will prove the computer theory that the suggested changes will produce a faster, more stable boat.

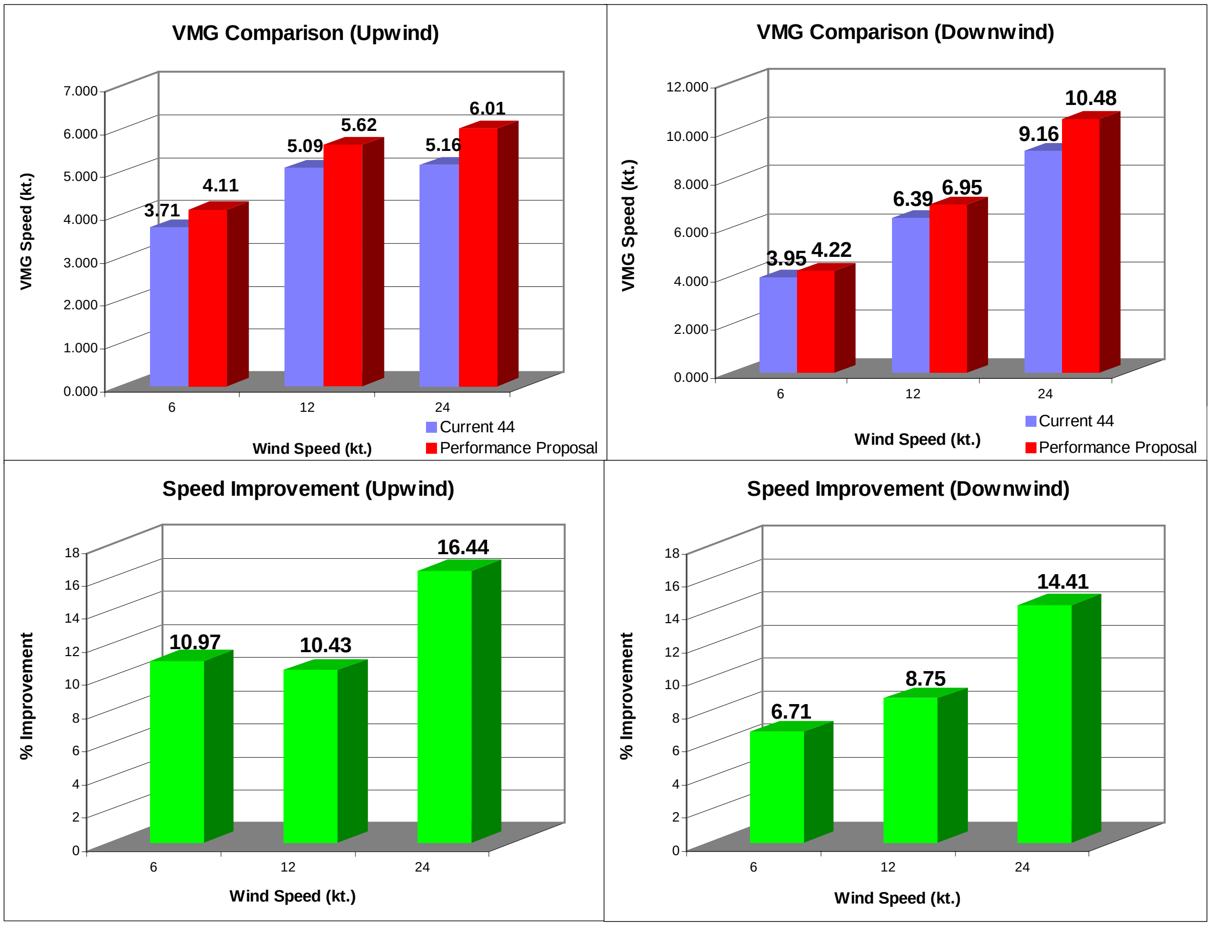
A final suggestion for changes: No effort has yet been made to modify the rudder. A study laid on for the summer has not begun as yet, but changes to the rudder should cause changes in displacement, wetted surface area, and hydrodynamic properties. Likely, an improved rudder will further reduce resistance, and help improve the boat's pointing ability.

## CONCLUSIONS:

VPP data confirms the theory that increased waterline length, decreased displacement, and change in hull shape and appendages increases boat speed. In addition, these changes reduce resistance, allowing for smaller powering requirements while motoring. Of the changes, waterline length proved the most dramatic for speed. For stability, the CG shift of the keel provided the most assistance. The following bar graphs depict the VMG speeds of the mid-line proposal compared to the current boat. Note the percent change in speeds upwind and downwind. **(Fig. 1-4 mid-line)**



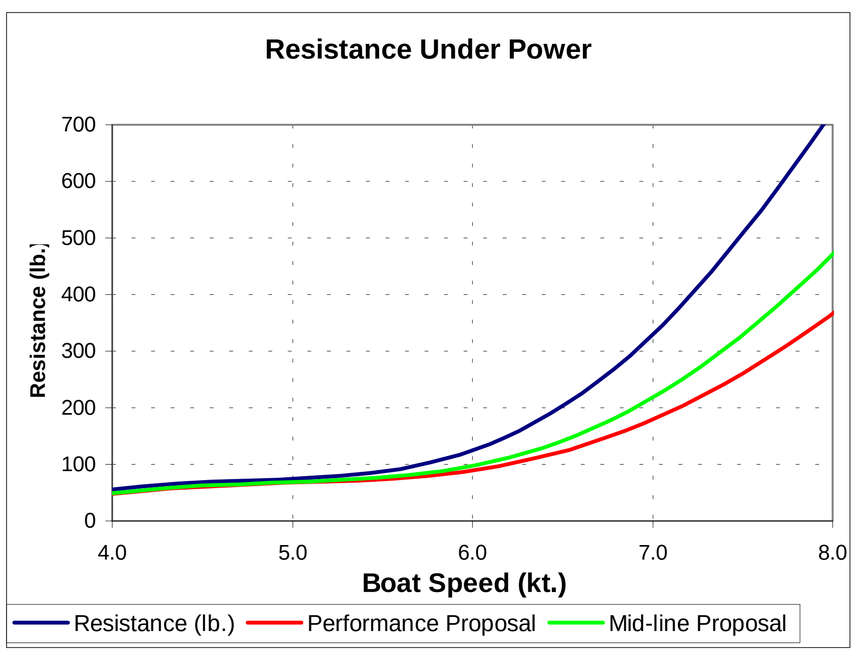

Similar but more dramatic values were achieved with the performance proposal. Graphed data clearly indicates that the proposed new hull forms cause dramatic improvements in performance. Simply put, a few




**(Fig. 5-8 performance)**

relatively minor changes to the current design allow for a faster, more stable boat. More research data is attached to this report. Polar plots of boat speed comparisons for both the mid-line and performance proposals are included in the annex.

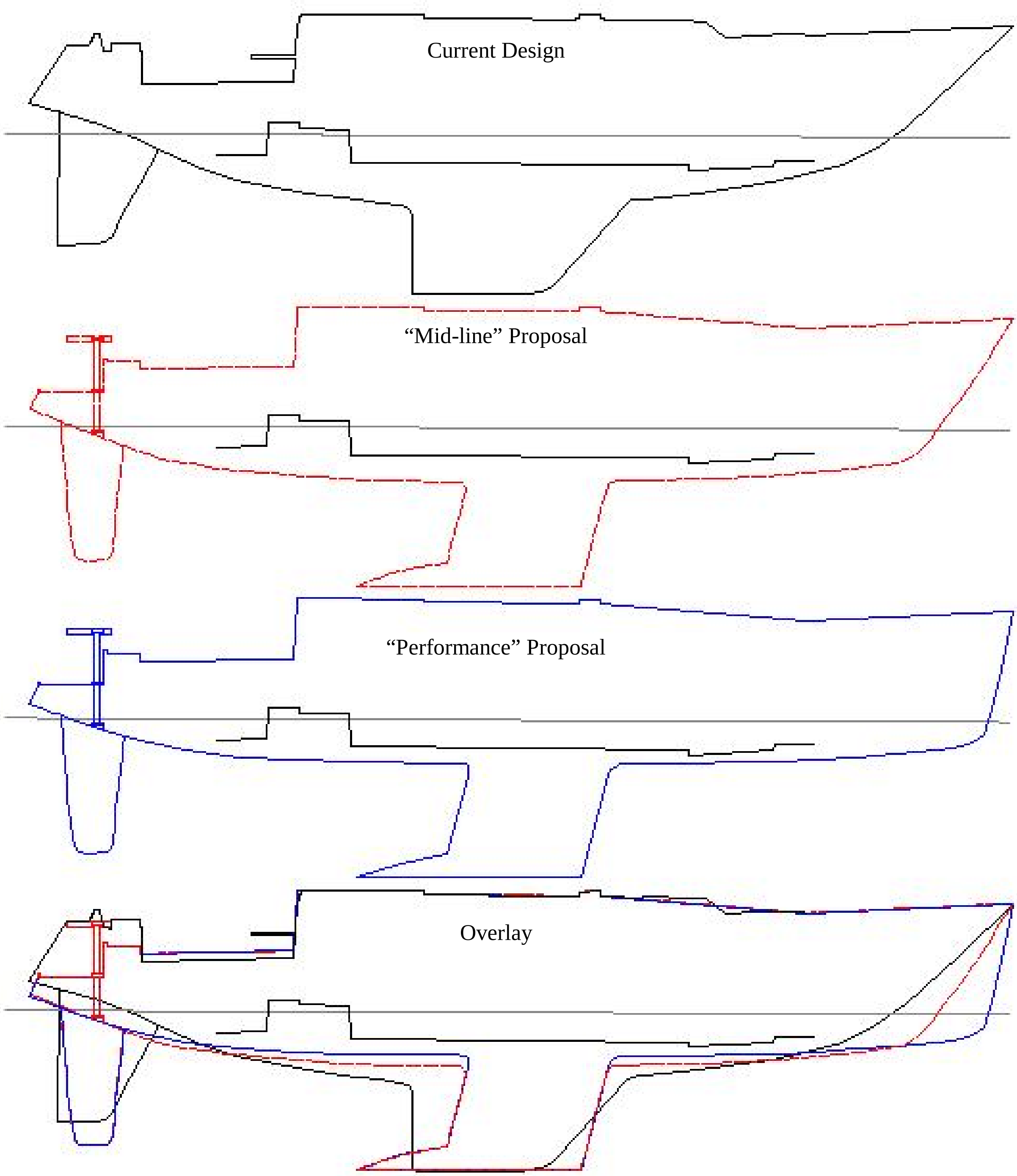
In a practical sense, these suggestions translate to three important benefits to Navy sailing. First, the higher speed ensures quicker transit times. This will improve scheduling difficulties for CSNTS and VOST cruises and ensure greater safety for midshipmen. Second, the faster sailing speeds of the boats will ensure more actual time under sail. This increases the training aspect of summer cruises in the sailing program. Finally, as the resistance graph above shows, reduced resistance at cruising




**(Fig. 9 Resistance Curve)**

speeds translates to lower wear on engines, smoother motoring, and lower fuel bills, all of which benefit the overall program. According to VPP data, at about 6.2 knots boat speed (a reasonable cruising speed for the current design), the current boat generates about 150 pounds of resistance. At the same resistance, the mid-line proposal could produce as much as a quarter to half knot improvement in motoring boat speed, while the performance proposal could generate even more.

**Navy-44 Design & Proposals:**



The above centerline profiles of hulls and appendages represent the suggested design modifications as tested in the VPP. The two proposed designs also comply with the new keel concept and the suggested modifications to the deck layout. The line present in the center of each drawing above represents the location of the current design's cabin sole.