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Early-Stage System-Level Optimization of a Fast Planing Monohull

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The advantages of early-stage design space exploration (DSE) are well-recognized in the fast ship design community. DSE can significantly influence both fundamental design and business decisions, and it can enhance the effectiveness of subsequent simulations that employ resource-intensive higher-order codes. This study examines the potential of resource-efficient reduced-order simulation via semi-empirical parametric prediction models to provide valuable early-stage DSE. A systematic comparison will be given to an existing comprehensive 11-meter planing craft R&D project (AutoPlan). The reference project included viscous CFD predictions, towing tank tests, and full-scale sea trials. Hull form shape variants are developed using the parametric CAD features of the CAESES® shape optimization platform and will be coupled with the NavCad® hydrodynamic and propulsion system simulation tool rather than CFD for performance simulation. The goal is to follow the same design path as the previous R&D project for side-by-side comparisons of outcomes and resource expenditures, while also setting the stage for follow-on consideration for the evaluation and selection of drive systems.

KEY WORDS: Design, High Speed Craft, Optimization, Powering Estimation.

INTRODUCTION

The design of high-speed craft is increasingly shaped by digital modeling tools that aim to accelerate development cycles while maintaining or improving vessel performance. Early-stage Design Space Exploration (DSE) plays a crucial role in this process, enabling informed decisions regarding hull form, propulsion, and operational efficiency before committing to more detailed and computationally expensive simulations. While high-fidelity models such as RANS-based Computational Fluid Dynamics (CFD) provide reliable performance predictions, their significant computational demands can be prohibitive, especially for smaller design offices or during the initial stages of product definition.

This study investigates whether reduced-order simulation tools can offer sufficient fidelity to support early-stage DSE, thereby reducing time and resource requirements without compromising the quality of design decisions. We systematically evaluate this by benchmarking a reduced-order approach against a comprehensive design, test, and validation campaign from the AutoPlan project. The reference project involved an 11-meter planing monohull, optimized for a cruising speed of 27.5 knots and a displacement of 9.5 tons, featuring propellers in tunnels along conventional shaft lines. Its development incorporated hull form shape optimization with CAESES utilizing several free-form geometric hull shape parameters and coupled with RANS-based CFD for performance simulations (which were validated against towing tank experiments).

Building on this foundation, our study applies a similar parametric hull form variation strategy (albeit with fewer shape parameters for clarity) but replaces the high-fidelity CFD simulations with performance predictions using NavCad. Through direct comparison of predicted critical performance characteristics – including propeller force, dynamic trim, and total resistance – against the results of CFD and experimental tank tests, we aim to assess the accuracy, resource savings, and practical utility of semi-empirical reduced-order methods in early-stage ship design. Moreover, we investigate vertical force components originating from inclined shaft lines and trim angles, an effect often missing from conventional CFD actuator disk models but influential on the running attitude and propulsion efficiency of high-speed craft.

The methodology combines parametric shape modeling, hydrodynamic prediction, and validation against experimental data and fully-computational models, with special attention to the limitations and trade-offs inherent in using semi-empirical reduced-order models. The key outcomes of this work include a practical assessment of simulation fidelity, insights into computational resource savings, and recommendations for integrating drive considerations early in the design process.

Ultimately, this study aims to demonstrate that, when used strategically, semi-empirical reduced-order tools can meaningfully support rapid exploration of design variants, streamline early-stage workflows, and complement higher-fidelity approaches – thereby contributing to a more agile, efficient, and innovative naval architecture practice.

PROJECT SUMMARY

The baseline for this work is an 11-meter monohull design optimized during the AutoPlan project. That vessel featured tunneled propellers and conventional shaft lines, driven by twin 300 kW diesel engines, optimized for 27.5 knots at 9.5 tons displacement. The hull was defined for shape optimization through a parametric model with 18 shape variables and evaluated through CFD simulations, model testing, and full-scale sea trials.

Additional source data used in the paper for the original AutoPlan project, model testing, and CFD analysis can be found in the noted references [Harries 2024][Hochbaum 2024][Ahmed 2022].

Table 1. Reference craft specifications

Parameter	Full-scale	Model-scale
Length OA	11.06 m (36.3 ft)	3.364 m
Beam OA	3.5 m (11.5 ft)	1.065 m
Design displacement	9.74 t SW	0.267 t FW
Propeller diameter	0.559 m (1.83 ft)	0.17 m
LCG from transom	4.945 m (16.2 ft)	1.504 m
VCG from BL	0.7 m (2.3 ft)	0.213 m
Design speed	27.50 kn	7.80 m/s
Vol Froude number	3.12	

DESIGN SPACE EXPLORATION

The principal purpose of a Design Space Exploration (DSE) study is to narrow the focus of a set of possible design variants to those that meet a particular “objective function”. In many cases, we find that DSE objective functions are selected or constrained to a subset of the full *Vessel-Propulsor-Drive* system, such as focusing an optimization to minimum bare-hull drag. However, drag is not the real “cost” of the system. The analysis must be carried out through self-propulsion optimization of minimum drive power (or even fuel consumption or greenhouse gas production) to account for propeller size restrictions, hull-propulsor interaction, and propeller effects related to drive line design, such as shaft angle. A simplified optimization with fully-computational CFD is often done to budget a “reasonable” resource time and cost expenditure, but it does limit the DSE to a potentially myopic “snapshot” which may, or may not, be appropriate.

In the case of planing hull DSE, the necessary equilibrium solution must include – to the fullest extent possible – <u>all</u> forces that contribute to the force and moment balance [MacPherson 2024]. In both the original project and the current DSE described herein, the simulations did include at minimum a Vessel-Propulsor self-propulsion equilibrium solution.

Fully-Computational DSE (FC-DSE)

CAESES was the original DSE executive for hull CAD shape manipulation, data transfer and launch of the simulation, and optimization. Simcenter STAR-CCM+ was the RANS CFD tool used for simulation. The simulation modeling is:

- Optimization function: propeller delivered power
- Model-scale* equilibrium *Vessel-Propulsor* forces and moments
- Vessel resistance includes bare-hull and windage drag
- Hull-propulsor interaction is inherent in the RANS computation
- Propulsor modeling is by an actuator disk “virtual propeller” for thrust-line forces

Optimization and simulation for the original FC-DSE was conducted with a High-Performance Computing (HPC) Cluster with 40 cores and 90 GB RAM running Linux. The computation time for each optimization+simulation variant in the FC-DSE study was, unsurprisingly, dependent on the CFD mesh size. Models including the necessary resolution for simulation with appendages (approximately 3.7e6 cells) took approximately 5 hours per case. Without appendages and the smallest mesh size that did not meaningfully alter the simulation (approximately 8.3e5 cells), the computation time was reduced to approximately 2.5 hours per case [Ahmed 2022].

* Model scale calculations were conducted for the FC-DSE activities in the interest of CFD resource management.

Semi-Empirical Reduced-Order DSE (SERO-DSE)

Following the same approach as was conducted in the FC-DSE, CAESES is again used as the executive for hull form shape development and design optimization in the SERO-DSE utilizing the identical geometric model as in the FC-DSE study. NavCad is providing semi-empirical reduced-order prediction calculations for all aspects of the simulation.

- Optimization function: propeller delivered power and driveline mechanical shaft power
- Full-scale* equilibrium *Vessel-Propulsor-Drive* forces and moments (including shaft line power transmission)
- Vessel resistance includes bare-hull drag (with a model for oblique propeller stern lift), windage drag, and appendage drag
- Hull-propulsor interaction is from a twin-screw planing hull model with corrections for tunnel hull variation
- Propulsor modeling is by systematic propeller series (aligned to expected performance of a commercially appropriate propeller) for both thrust-line and propulsor lift forces

In comparison, optimization and simulation for the SERO-DSE was conducted on a business-grade Intel i9 laptop with 32 GB RAM running Windows 11. The optimization+simulation variant computation time was approximately 30 seconds, for an FC-to-SERO variant computation time ratio of 18000 (or more, depending on mesh size).

* For SERO-DES, "full-scale" generally means calculation methods that are based on model-scale data sets of hull form and propeller series (and their corresponding prediction algorithms) expanded to full-scale using standard Froude- and Reynolds-based scaling techniques.

SEMI-EMPIRICAL REDUCED-ORDER SIMULATION

The technical usefulness of any DSE is only as good as the simulation – both its data model and its force model. Especially for planing hulls, it is critical not to omit forces (both thrust and drag forces) that contribute to the moment about its CG. While the influence of shaft line thrust is ubiquitous in most planing hull simulations, other force contributors are often overlooked for various reasons, including appendage and windage drag (at suitable centers of effort). One particularly important – and frequently missing component – is the propulsor stern lift force [MacPherson 2024].

Each hull form was evaluated to predict:

- Calm-water resistance, dynamic trim and CG rise (for model-scale validation and full-scale optimization)
- Shaft power, delivered thrust, and cavitation metrics (at full-scale)

Resistance Prediction

The simulations use an equilibrium forces-and-moments planing resistance method [Savitsky 1964][Hadler 1966]. Several extensions to the core method are applied in the method used in NavCad, including the determination of an effective deadrise for hulls with tunnels using a lift-based weighting, updated lift coefficients to support longer and more slender hulls (such as for catamarans), updated spray drag prediction properties to resolve model-scale viscous transition assumptions in the original method [Savitsky 2007], and prediction of added bow wave formation pressure drag for heavy or flat-running craft.

To include the effect of vertical propeller forces from inclined shafts, a propulsor lift estimate model is applied as part of the planing hull resistance prediction. This typically overlooked lift force estimates the resultant vertical components of the equilibrium shaft line thrust (as determined by the predicted total resistance) and its effect on trim, drag, and lift.

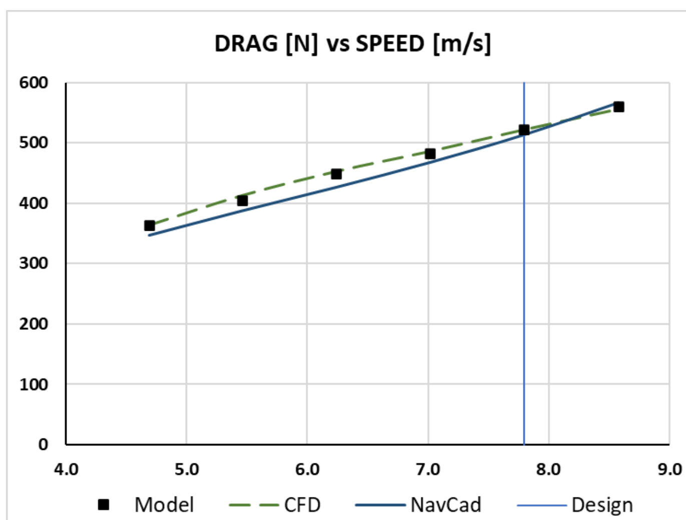
Additional drag forces necessary to complete a proper set of contributors for the simulation include prediction of the drag and lift of appendages, and windage drag for the exposed hull. A component-based prediction of the shaft, struts, and bossing was used for the model-scale validation, while a "simple" system-level model suitable for typical shaft-driven twin-screw planing craft was used for the subsequent full-scale optimization.

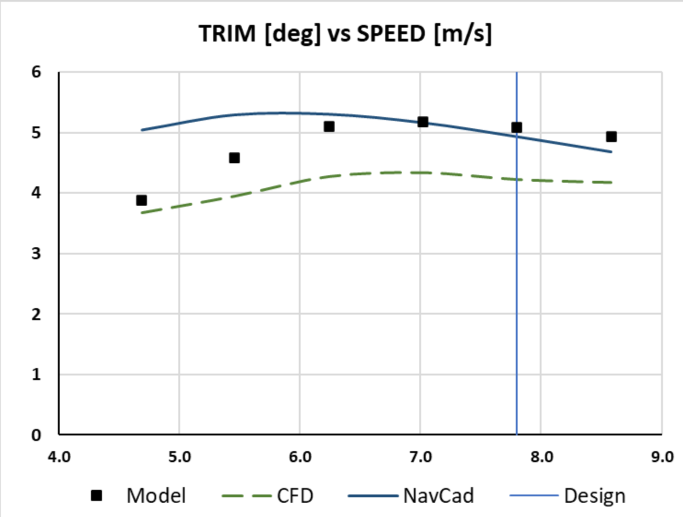
Resistance Validation

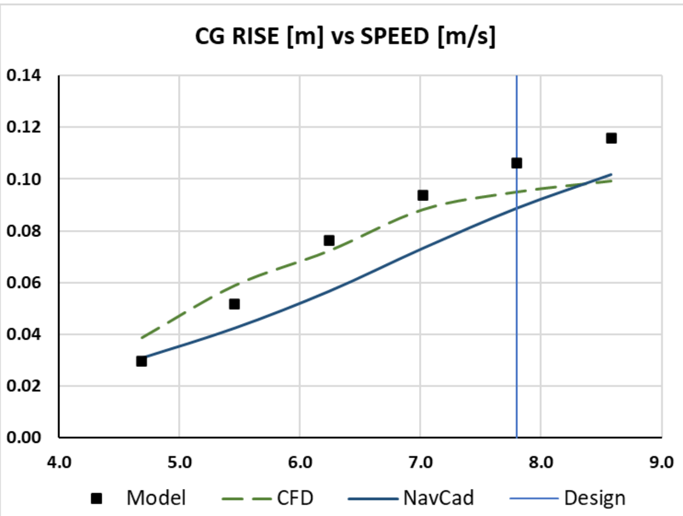
The planing hull resistance model has been previously validated against several standard benchmarks, including the NSWCCD GPPH (Generic Prismatic Planing Hull) [Lee 2017], UNINA Warped Hull Series [de Luca 2017], and the USCG Systematic Series [Kowalyshyn 2006]. For this specific project validation, the Baseline hull was run and compared to the model tests and CFD computations for the model-scale design speed (7.8 m/s). The simulation included consideration of the necessary forces and moments, including hull form centers of lift and drag, tow point and its direction (at a point positioned 0.900 m forward on the shaft line and in a horizontal tow force vector at all speeds ensuring compensation for dynamic trim), whisker spray (in a fully turbulent regime), windage drag (at the exposed hull center of effort), added bow wave pressure drag, and appendage lift and drag (at a defined center).

It is important to note that no unique or special combination of prediction settings was employed. The workflow process for preparing simulation settings utilized pre-defined "Standard" options for the application of the sub-components of bare-hull drag and the "Method Expert" utility for selection of the bare-hull resistance prediction method. (The same process is used for definition of hull-propulsor coefficient settings, and a similar approach for propeller performance settings.)

Since the project's objective was optimization at the design speed with no consideration of off-design influence on the objective function, the important validation – as it relates to the fidelity of the reduced order model for optimization in this project – is in the range of the design speed. That said, the authors did investigate off-design speeds and found that the semi-empirical reduced-order model fell victim to a well-established shortcoming of the Savitsky hull model which tends to under-predict drag for a hull riding low in the water and/or with a flat trim. This tendency is identified when the predicted "prismatic wedge" length of keel exceeds the actual hull length – which is the case found for the lower off-design speeds. This condition can develop a build-up of water from wave formation at the bow and chines that increases drag. NavCad provides an indicator (using the prismatic length-of-keel figure) to advise the user of this condition. It also employs an estimated supplement for the bow wave formation added drag, and its full simulation model does an excellent job at predicting drag, trim, and CG rise (Figures 2-4).







Figures 2-4. Validation plots of NavCad prediction versus original project model tests and CFD

Propulsion Free-run Simulation

The propulsion performance is determined via a "free-run" steady-state equilibrium between total drag and the horizontal component of the propeller developed thrust. The propulsion analysis to determine the Vessel-Propulsor equilibrium properties is in several steps:

1. Predict hull-propulsor interaction coefficients (wake fraction, thrust deduction, relative-rotative efficiency) using one of several planing hull models (with tunnel stern corrections).
2. Establish the per-propeller operation requirements of delivered thrust and speed of advance.
3. To consider a "best propeller" for each steady-state speed, apply a propeller sizing optimization step (within the larger variant optimization) that determines propeller properties for a thrust-based load objective). The sizing will determine appropriate shaft RPM, blade area ratio (per cavitation criteria), diameter (with a maximum diameter constraint), and the mean effective pitch. [See "Optimum Propeller Sizing" section below for additional technical details.]
4. Using the simulation's propeller model, solve for the RPM that generates the matching steady-state delivered thrust at the various speed(s) under consideration.
5. Calculate propeller performance, including thrust, power, efficiency, and cavitation metrics, as well as prediction of representative drive-line efficiencies, shaft RPM, and drive power.

Propeller Performance

Propeller performance is built upon similar reduced-order parameters using popular systematic propeller series. For this study, the "Gawn AEW" propeller model was selected as it represents the style of propeller most likely to be used for a small planing hull. Corrections to the basis propeller, however, are available to account for deviations from the original series geometry and test conditions. These include correlation multipliers for characteristics such as the effect of hub size or edge thickness (a 3% torque increase is applied), as well as scale correction from model- to full-scale (using the recommended "equivalent profile" method). Explicit geometric differences can also be applied for the addition of cupping or face camber (i.e., "progressive pitch").

As the simulation then evaluates the propulsion equilibrium, an oblique propeller performance correction is applied to determine changes in propeller thrust and torque for the given shaft angle. This addresses a known limitation when using basic open-water performance and contributes to a better real-world propulsion force model [Hadler 1966] [MacPherson 2024].

Optimum Propeller Sizing

As hull form variants change, the vessel's resistance changes and thus also its propeller thrust and power demand. To provide a proper correlation with the resistance change, a function is called to size a thrust-matched optimized propeller (for minimum power demand) as well as the corresponding shaft RPM (which can also be used for drive RPM and gear box reduction ratio selection). The thrust-identity target is calculated from the total resistance and prediction of thrust deduction (as part of the larger hull-propulsor interaction prediction step).

The procedure for optimum propeller sizing is a simultaneous solution of equations for solution of its own object function where a) a particular load is met (which can be a power demand or a thrust delivery), b) does so with acceptable cavitation limits, c) is limited to a pre-defined maximum propeller diameter (generally to establish a suitable tip clearance to the hull), and d) achieves highest propeller open-water efficiency. The component equations are series-based polynomials of J-KT-KQ optionally with modification described above. Cavitation limits are defined using one of several industry-standard operational criteria, which in this case is the 10% Burrill cavitation percentage line.

Parametric Hull Design and Optimized Variant Selection

To ensure consistency and enable direct comparison, this study reused the same parametric CAD model from the original FC-DSE, applying shape variables to generate hull form variants during optimization. The Baseline hull from the original project served as the initial model-scale validation case and as the starting point for full-scale optimization. The resulting optimized designs represent progressive improvements in refinement and hydrodynamic efficiency.

Compared to the original study, the number of shape variables was reduced by excluding variation in propeller tunnel stern details. This allowed greater focus on hydrodynamically significant parameters such as chine beam distribution, chine flat width, deadrise, and keel position at the transom. Propeller shaft alignment and appendage locations were unchanged between variants. Propeller disk "immersion distance" into the tunnel was captured (which affects the prediction of hull-propulsor interaction coefficients).

Optimization began with a design-of-experiments (DoE) approach, using several geometric parameters as free variables to generate a diverse set of hull variants. A quasi-random Sobol sequence was employed to efficiently explore the design space, inserting variants where data was most lacking. This method provided early insights into key relationships between performance and hull parameters. For example, transom keel position was shown to significantly affect both dynamic trim and resistance. Each DoE variant was created independently of prior outcomes, ensuring wide variation in hull forms and revealing promising areas in the design space for further exploration.

Local optimization using a T-search method then refined the most promising DoE variants [Birk 2003]. Unlike the DoE, the T-search builds on previous results, adjusting variables in a structured pattern to gradually improve performance. These local changes yielded steady gains in efficiency at the target design speed.

To further enhance optimization, machine learning techniques – particularly surrogate modeling – were introduced. Surrogate models were built from the DoE dataset to predict performance outcomes and guide new variant selection [Harries 2010]. Starting from a strong DoE candidate, this method identified additional configurations with improved energy efficiency.

Complementing both the direct and the surrogate-based optimizations, the SERO-DSE simulation allows for quick investigation of other naval architectural design objectives that are indirectly related to performance, such as the habitability effects of trim angle, dynamic stability (porpoising), or motions (e.g., acceleration and slamming), for example.

Coupling of the Optimizing and Simulation Tools

CAESES is the master executive for the optimization, with responsibility for a) hull form geometric modeling, b) passing data to the NavCad performance simulation tool, c) retrieving key performance simulation outputs, and then d) determining parametric hull form changes for the optimization objectives.

The coupling process is via NavCad-specific command scripts that are generated in CAESES (as defined within CAESES is a "Feature") and passed to a silent "calculation server" instance of NavCad that has been launched and waiting for instruction. NavCad then packages text-based simulation results in a pre-defined output file that CAESES picks up when a polling function determines that new results are available. (An example of the script used for data transfer is shown in the Appendix.)

Hull form data is passed as a 3D CAD file (in STL format) which NavCad then automatically interrogates for planing-specific data, such as chine points, key station offsets, as well as hydrostatic properties. Simulation settings are typically pre-determined by a configuration step where the initial geometry is evaluated in a full NavCad GUI session. Proposed prediction methods are evaluated and selected with the "Method Expert" utility, and appropriate models for added resistance, propulsor settings, and drive-line properties are defined. This establishes confidence in the simulation for the initial baseline and requires only the changing hull form geometric model (and potentially other key parameters, such as shaft angle or CG position, for example) to be updated for the simulation computation.

After retrieving the variant simulation performance output, CAESES then modifies the hull form into a new variant using one of several optimization approaches described above.

Optimization Evolution and Design Guidance

Various plots and images document the trends observed during the DSE process, which can also then be used to provide addition design guidance. Sobol DoE charts, like the one below (Figure 5), provide indicators of trends (linear and quadratic) for the influence of a single free variable (rows) versus resulting performance outputs (columns). Trends that are nominally flat (in both linear and quadratic form) are indicative of variables that have little influence, and these parameters might then be omitted or additionally constrained from follow-on Sobol or T-search analysis. Coloring of the cells from red (high correlation) to green (insignificant correlation) can aid in the visual identification of key trends.

Another way to communicate trend influences is with "design velocity" graphics, as shown below (Figures 6 and 7). These compare the geometric change from the Baseline hull to an Optimized variant (via the normal vector distance between the two). Coloring is blue for Optimized geometries that are "in to" the Baseline hull, and red for "out of" the hull.

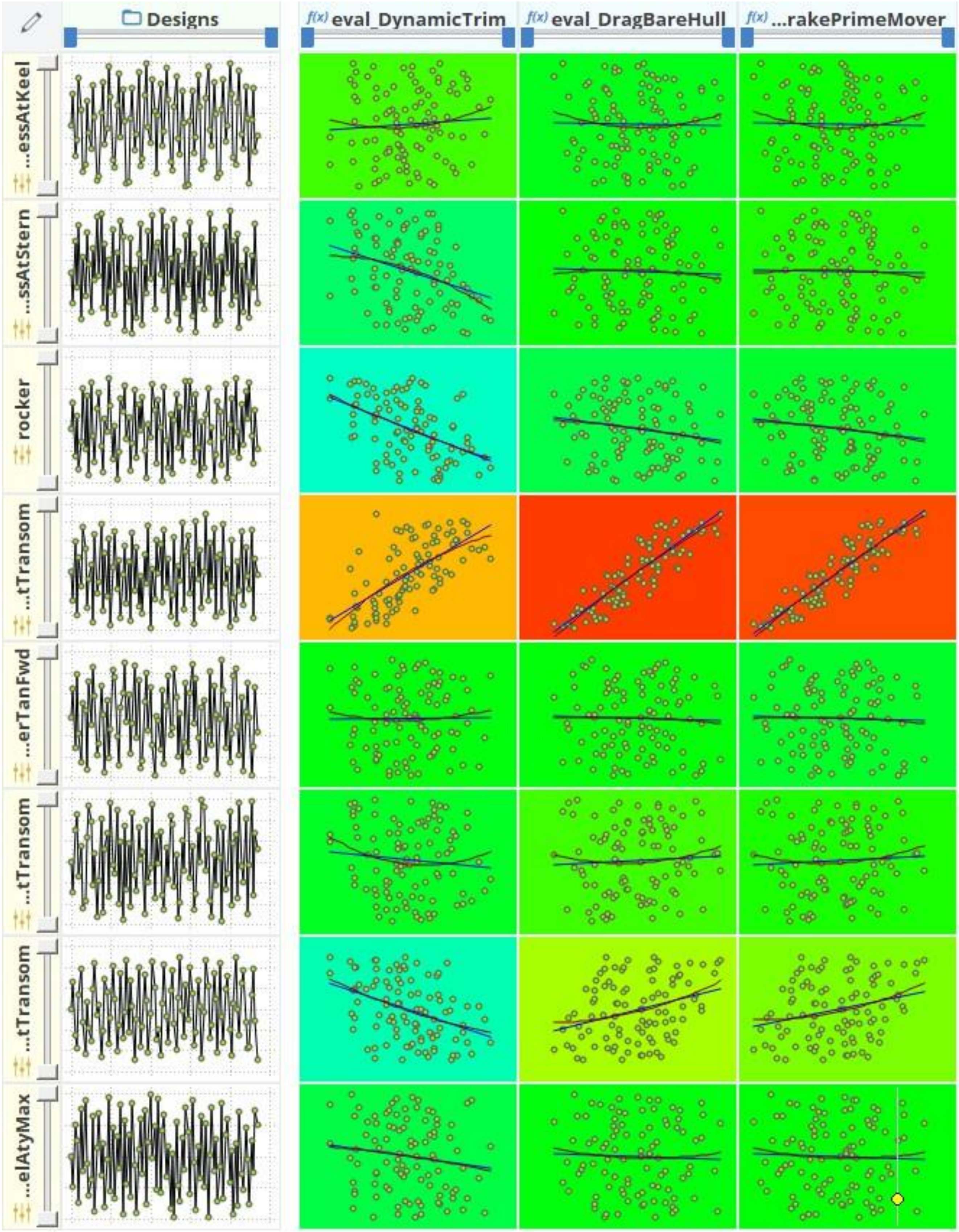


Figure 5. Sobol DOE plots

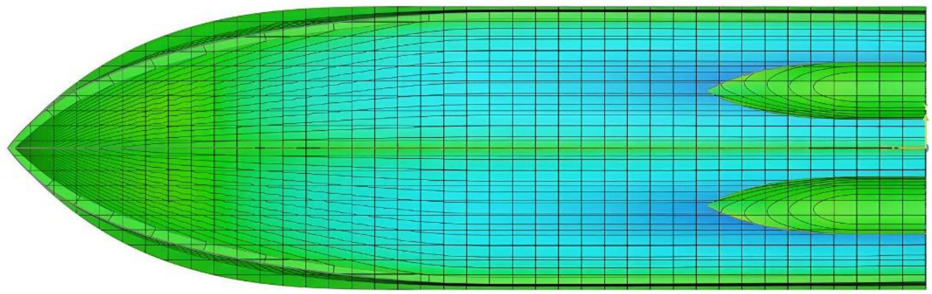


Figure 6. Design velocity for the parameter that controls hollowness of the bottom surface

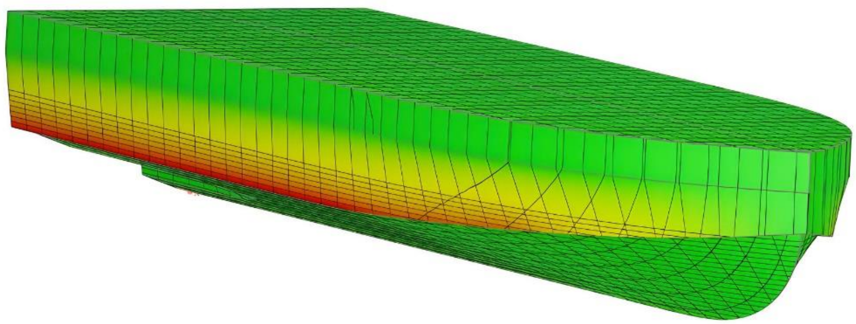


Figure 7. Design velocity for the parameter that controls the transverse width of the chine flat

The hollowness image (Figure 6) describes how the linear deadrise of the Baseline is changed to a cambered section (also see the solution hull comparison, Figure 8). The other image (Figure 7) describes how the transverse width of the chine flat increases from the Baseline to the Optimized hull.

Of course, naval architectural design priorities are varied, and not all geometric changes generated by a hydrodynamic DSE optimization will necessarily be utilized due to competing design requirements. The feedback provided by DoE trends and design velocity plots aid in making critical technical and business decisions by exposing the correlation strength or weakness of the individual shape variables.

RESULTS

SERO-DSE Full-Scale Optimization

The results of the SERO-DSE optimization simulations for the full-scale ship at 27.5 knots are shown below. The improvement in total drag was 11.9% and 14.9% for developed shaft power.

Variant	*Total Drag (kN)*	*Trim (°)*	*Shaft Power (kW)*
Baseline	16.8	4.3	2 x 195
Optimized	14.8	4.0	2 x 166

Comparison to FC-DSE

Unfortunately, direct comparison of full-scale resistance and power magnitudes with the FC-DSE is not available for several reasons. First, the FC-DSE optimization was conducted at model-scale with no appendages (although a final model-scale validation of thrust and power included appendages). Second, full scale power was determined using simplified scaling whereby the model-scale power (with an actuator disk virtual propeller) was multiplied by the geometric scale ratio raised to 3.5 power. (The original project deliberately deviated from the standard ITTC expansion for HPMVs.) Third, the influence of propeller lift on drag and trim was absent in the FC-DSE actuator disk model.

Comparisons can be made, however, using relative differences between Baseline and Optimized simulations at model-scale – which were 10.9% reduction is shaft-line thrust (which would correlate to a reduction in drag and compare to 11.9% in the SERO-DSE) and 11.6% reduction is shaft power (comparing to 14.9% power reduction in SERO-DSE) [Ahmed 2022, table 14]. Of course, comparison of the SERO-DSE with the FC-DSE should include the geometric similarity between their ultimate optimized hull forms (Figure 8).

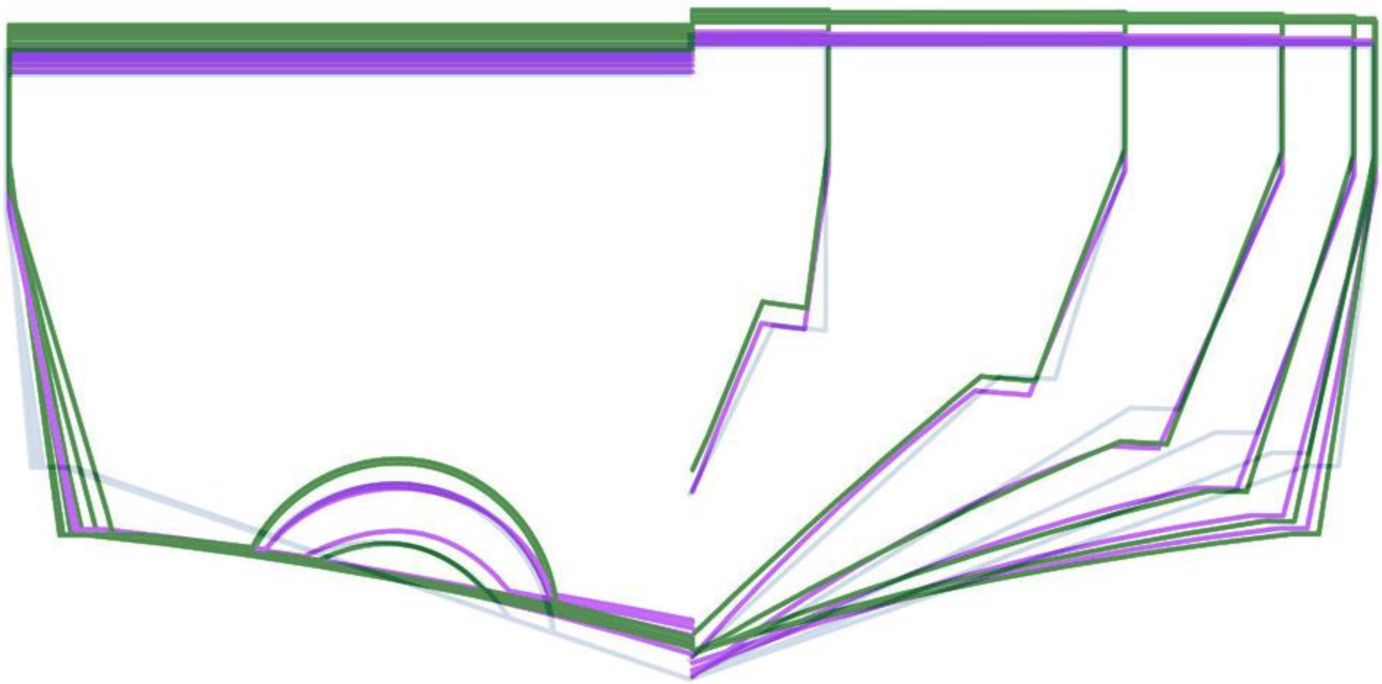


Figure 8. FC-DSE (purple) and SERO-DSE (green) optimized hull forms; Baseline (blue background)

The two projects produced optimized hulls that were very similar in their characteristics. Both shift chines inward and down with a rising keel (for flatter deadrise). The FC-DSE solution has a somewhat higher static draft than the SERO-DSE (for the same immersed volume) through a narrower chine beam and a deadrise distribution that is a bit higher forward and flatter aft (for more "bottom warp").

Computational Efficiency

As mentioned above, the most time-efficient fully-computational CFD simulations required several hours on HPC resources for a single design variant. Upfront preparatory tasks would include selection and definition of turbulence and time step settings, mesh generation settings (including refinement requirements for detailed structures such as appendages and the actuator disk region), and grid convergence checking.

In contrast, the semi-empirical reduced-order simulations ran on a business-grade laptop in under a minute per variant. Initial calculations configuration employed Standard "best practices" planing hull settings, thereby allowing a user to configure and run the entire SERO-DSE optimization and simulation in less time than it takes for a single variant to be run with the FC-DSE higher-order HPC RANS CFD simulation.

FUTURE WORK

The authors intend to enhance the coupled optimization-and-simulation of this study to include the following:

- Duty profile optimization. This will extend the focused design point optimization to include the performance at off-design speeds. By defining a time- or distance-based duty profile, the objective function can be total mission fuel consumption including the effect of IC engine and electric motor partial load efficiencies.
- Observation of additional performance parameters. While efficiency at speed is a typically key optimization parameter, the "optimum" design may, or may not, exceed other design criteria. It is important for corollary performance parameters to be included in the optimization for review. These parameters will include longitudinal and transverse dynamic stability (i.e., porpoising), as well as seakeeping parameters (i.e., impact accelerations in irregular seas).
- Refinement of shape parameters. A new prediction model for the stern lift associated with propeller tunnel aft exit curvature is in development.

CONCLUSION

This study demonstrates that semi-empirical reduced-order simulation, when combined with automated shape optimization, provides a powerful and efficient framework for early-stage marine design. Although it does not capture fine-scale flow phenomena – such as vortex dynamics within propeller tunnels – it reliably replicates qualitative performance trends and rankings. This validates its use as a front-end filter for exploring design variants, guiding investment decisions, and setting benchmarks for more detailed CFD analyses or physical testing.
The methodology employed for this study enables teams to:

- Rapidly evaluate performance trends across design variants

- Identify promising hull forms for further refinement – use the SERO-DSE as the baseline for FC-DSE
- Extend the simulation to include evaluation of driveline options
- Understand the influence of key geometric parameters on trim, lift, and resistance

While not intended as a replacement for high-fidelity simulations or model testing, semi-empirical reduced-order tools significantly lower the barrier to robust design space exploration. Their use promotes earlier, data-informed decision-making and supports the broader adoption of energy-efficient, next-generation marine systems.

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APPENDIX – EXAMPLE DATA TRANSFER SCRIPT

The format for data exchange employs NavCad’s object-oriented scripting API. The scripts should address the modifications to the project that are relevant for each variant. This includes not only the hull form data (of course), but also a locally optimized propeller and electric motor definition for each variant. Examples of key scripting tasks are shown below.

```
' hull CAD import (data to be set here as these settings are not saved to a project)
HullImport.Orient -90 0 0
HullImport.Import m overwrite "variant##.stl"
HullImport.Scope Planing
HullImport.HullConfigType Monohull
' hull pre-floated to waterline
HullImport.SetWaterlineTrimAndDraft 0 0 m
' insets from bow/stern
HullImport.Stations standard 0.01 0.01 %
HullImport.Build

' calc resistance (all settings pre-defined)
Analysis.CalculateResistance

' propeller and gear ratio (shaft RPM) sizing (optimized for total drag/thrust)
PropellerSizing.GearRatioSolution Size
PropellerSizing.ExpAreaRatioSolution Size
PropellerSizing.DiameterSolution Size
PropellerSizing.PitchMeanSolution Size
PropellerSizing.PropellerSizingIdentity ByTotalDrag
```

```
' run propulsion analysis for design speed sizing and power demand across all speeds
Propulsion.DriveLine NoneDefined
Analysis.CalculatePropulsion

' push key results to pre-defined output file
Output.Start output.txt output.lock
' confirm key data
Hull.AddToOutput Displacement
' performance parameters
SpeedPerformance.AddToOutput Count
SpeedPerformance.AddToOutput DesignSpeedIndex
SpeedPerformance.AddToOutput Speed
SpeedPerformance.AddToOutput DynamicTrimObservedDeg
SpeedPerformance.AddToOutput DragBareHull
SpeedPerformance.AddToOutput PowerBrakePerPrimeMover
Output.End
```