The first voyage happens far from the sea

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Ships are designed to a specification. Yet that starting point – calm waters, a single design speed, and constant draft – rarely mirrors the varied conditions encountered at sea. Operational simulation (OpSim) lets naval architects and engineers test a ship in realistic operating conditions already at the concept stage.

Ask a naval architect how a new ship will cope with the weather on its intended route, and the answer will generally involve a percentage. Ship designers typically assess performance based on data from comparable vessels, using a limited set of metrics such as the Energy Efficiency Design Index (EEDI) and contractual powering curves at design speed. To this, they will then add a sea margin, often between 15 and 25% to cover waves, wind, fouling, and everything else the ocean brings. This is a proven process, but it falls short when evaluating novel design concepts.

Meanwhile, the EU Emissions Trading System, FuelEU Maritime, and the International Maritime Organization's (IMO) Carbon Intensity Indicator (CII) now all judge ships on how they perform in service, year after year. A design can clear its EEDI requirement at delivery and still be on course for a D or E CII rating once it starts trading. This quickly becomes a commercial and regulatory liability for shipowners, with limited cost-effective remedies available at that stage.

The growing number of clean technologies competing for a place on board also makes the performance question harder to answer. Over 100 commercial vessels now carry wind-assisted propulsion systems, adding up to over six million deadweight (dwt) of capacity, according to the International Windship Association. Air lubrication is also increasing in popularity. Each tech solution promises emissions and fuel savings, but those efficiencies depend on the route, the weather, and how the ship is sailed – and how each technology interacts with the others. Owners need certainty on which tech combinations suit their vessel for a specific trade route.

The process works – with limits

Simulating the performance of a vessel is not new. It usually involves three key steps, uses existing digital tools, and starts with creating a hydrodynamic model to reflect how a specific ship will perform at various speeds and in different sea conditions.

The NAPA Performance Model, which has a baseline for all vessel types and sizes worldwide, offers a framework for hydrodynamic modelling, which can then be refined using new design data. The model is then further defined using an operational plan that reflects the areas the vessel will be operated in and the ports it will visit. It includes the range of speeds to be considered, as well as the loading conditions it will experience. This is easier for retrofitting projects, where we already have a detailed picture of a vessel's operations. But for newbuilds, a lot of insight can be gained from AIS data, which is then analysed by AI to contextualise it by vessel type and size. This provides invaluable information about how ships tend to be operated in any given area and for any vessel type. The final step involves simulating realistic voyages by bringing the hydrodynamic model and operational plan together (this can be done on NAPA Voyage Optimization to simulate multiple route variations).

While functional, this approach has historically required separate tools, data preparation, and teams – and was rarely done at the concept stage, exactly when decisions with the greatest influence on lifetime fuel costs and regulatory exposure are made.

Only as good as the data behind them

Hydrodynamic calculations, voyage and routing optimisation, and hind-cast weather data are now being brought together in the design process using NAPA Operational Simulation. It works from the design model the team has already built as above, with nothing re-entered. The results include a projected CII trajectory, FuelEU Maritime compliance balance, and EEDI under realistic conditions. Design teams have not normally had these figures at the concept stage.

Several design decisions change as a result when designers get the full spread of power the ship will need on its route. They can then size the main engine against a high percentile of that spread rather than a rule of thumb. Fuel tanks can be sized around expected consumption between bunkering ports. Hull form alternatives can be judged across the speeds and sea states the ship will really experience.

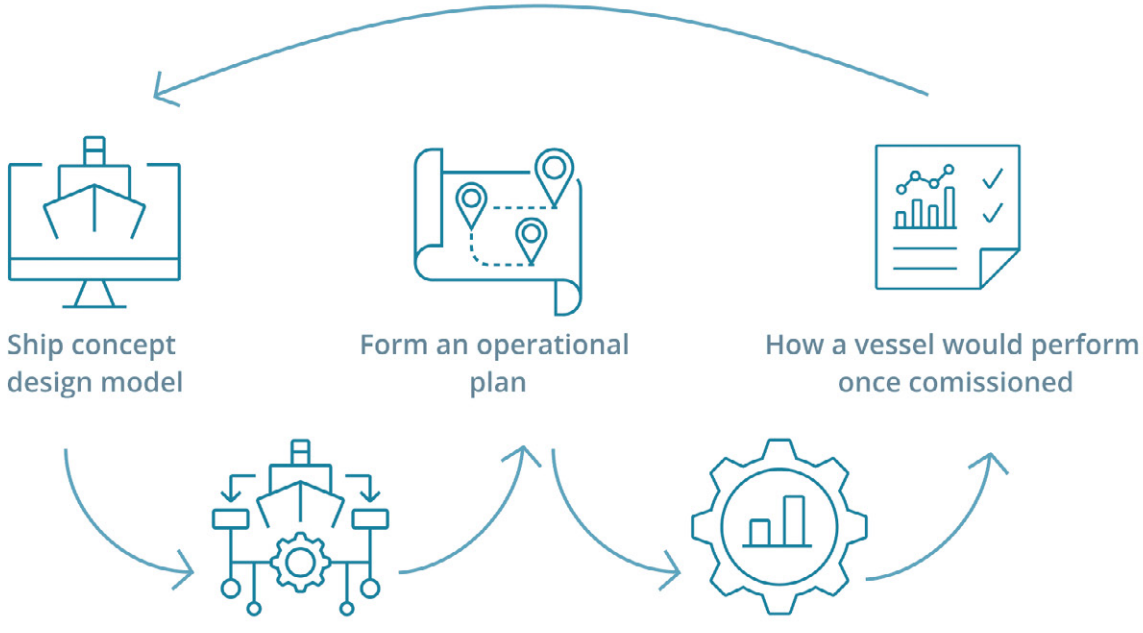


Photo: NAPA

A wind-assisted propulsion or air lubrication system is tested in the same conditions the vessel will experience, so the projected fuel savings go beyond a supplier's estimate.

To show what this looks like in practice, we ran four configurations of a capesize bulk carrier on the Port Hedland to Pohang iron-ore route, across 11 voyages covering five months of real hindcast weather. The hull form is the Japan Bulk Carrier benchmark, extensively validated internationally, and the engine operating point was held constant, so differences come entirely from design and routing choices.

The configurations were: baseline, baseline with optimised routing, sail alone, and sail with optimised routing. Weather routing alone reduced fuel use and cost by 1.6%. Sails without routing saved 6.6%. Sails and routing together cut fuel consumption by 8.0% and cost by 7.9%.

The regulatory compliance predictions showed that, on this trade, the design's attained CII was around 5.3 grams of CO_2 per dwt-nautical mile against a 2030 requirement of 2.27, which puts it in the E band. Its attained EEDI was 16% above the Phase 3 limit. Neither issue would emerge from a calm-water analysis. Identifying both at the concept stage allows time to adjust the powertrain, integrate wind assistance, or reconsider fuel selection.

The headline numbers are promising but need careful evaluation. The gap between two configurations is a more reliable guide than any single fuel consumption figure, and simulation at this stage is best used to compare options under identical conditions and to identify regulatory risk early, not to promise an exact outcome. Results are also only as good as the design data behind them, so uncertainty is higher for newer technologies such as wind propulsion, where the industry is still building up validation data.

OpSim is a design tool, not a one-time assessment. Each iteration refines the inputs, and the performance model becomes more accurate as the design matures. A concept-stage simulation gives a directional answer; the same model, updated through concept to delivery, gives an increasingly precise one.

Design-operational feedback loop

Commercial teams are starting to acknowledge how OpSim can provide greater operational clarity earlier. The same design model can stay with the ship after delivery for operational benchmarking and retrofit studies, and data from vessels in service can then inform the next design. The long-term payoff is a feedback loop that unites design and operational data, which have long been separate disciplines with their own distinct tools. For owners making capital decisions that need to hold up for 25 years, that separation is turning into an expensive habit.

The first contracts to include performance data are already on the market. In March 2026, NYK and Japan Marine United agreed on a crude tanker contract that guarantees performance in actual sea conditions. The deal also shares the benefits between the shipowner and yard according to how well the vessel performs. Another strong signal of interest has come from Samsung Heavy Industries (SHI). In June 2026, the company signed a memorandum of understanding with NAPA to use OpSim to implement digital twins of ship equipment and predict vessel performance from the initial design stage, building on a joint project active since May 2026 on SHI's SAVER Wing wind-assisted propulsion system.

These simulations make naval architects' judgement even more crucial. They still need to decide which design variants are worth putting to the test, which inputs need sensitivity testing, and when a result looks more precise than its inputs justify. That remains the naval architects' job and is a gauge of their experience. What changes is that the work gets done with much clearer data on the actual conditions the vessel will face at sea. □

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