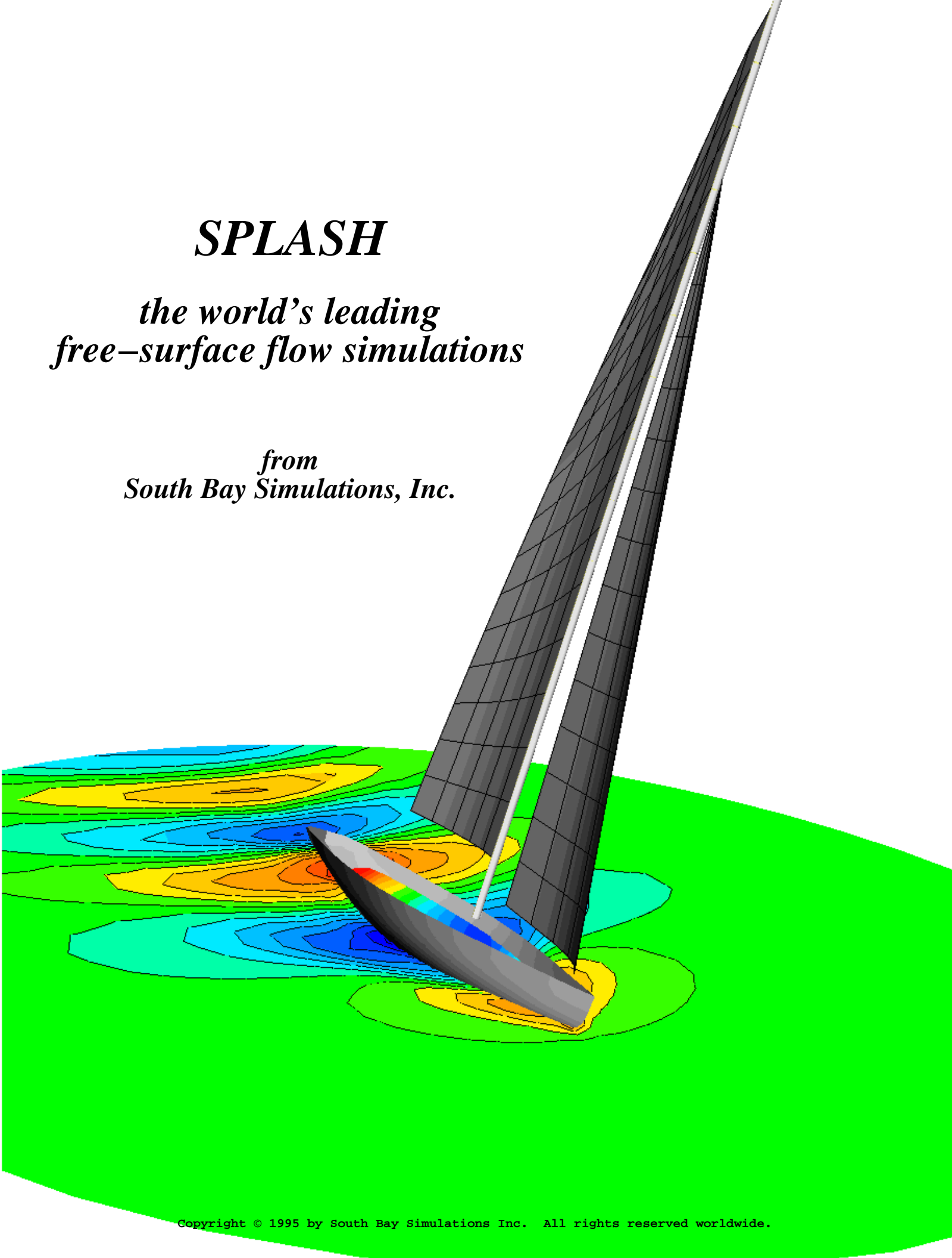


SPLASH

*the world's leading
free-surface flow simulations*

*from
South Bay Simulations, Inc.*



Introducing SPLASH Software and Consulting Services

***Technology for aerodynamic design and analysis of
complex aircraft ...***

Free-surface flow simulations ... for accurate, detailed flow information, and prediction of integrated vehicle characteristics

Start with state-of-the-art flow simulation technology for complex 3-D vehicle geometries. Add reliable, robust and accurate free-surface wave boundary conditions. Develop automated hydrostatics and panelization packages, with free to sink and trim and steady nonlinear free-surface capabilities. Then extend simulations to the frequency domain, to treat unsteady flows, including prediction of seakeeping motions and added resistance in waves.

The result is SPLASH ... the world's leading free-surface flow simulation software, and the closest thing to a "numerical towing tank" the world has seen yet.

We have been developing and improving SPLASH software for over a decade, with a proven track record of success, providing engineering consultation services for applications ranging from grand prix sailing yachts to oil tankers and submarines. And with a commitment to problem-oriented research and development, which helps keep us and our customers on the cutting edge of technology.

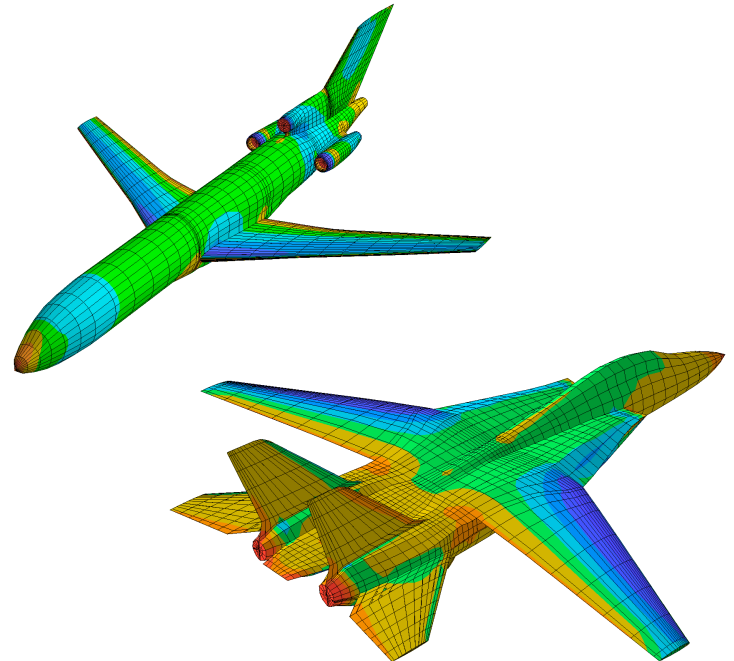
Use SPLASH alongside, or in lieu of, towing tank tests. Numerical analysis can be quicker and more cost effective than model or full-scale testing, and in some situations provides information of similar, if not better, quality. Experience shows that using SPLASH and the tank together enhances the value of data derived from each source alone.

For answers to today's problems, consider using SPLASH, with software licenses to run software at your site, or through our engineering design and analysis consultation services.

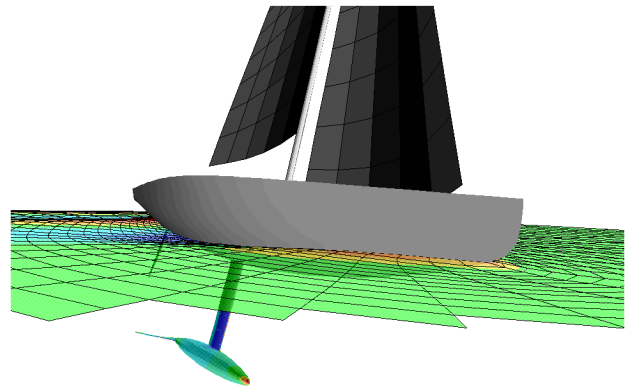
You can benefit from SPLASH technology if you're involved in research and design relating to:

- grand prix race yachts, including America's Cup, Whitbread, IMS/ILC, one designs, etc.
- large ocean cruising yachts
- ships, both military and commercial
- submersibles
- vehicle Kelvin wake signatures
- any other type of flow or vehicle where waves at the air/water free-surface interface are of paramount importance

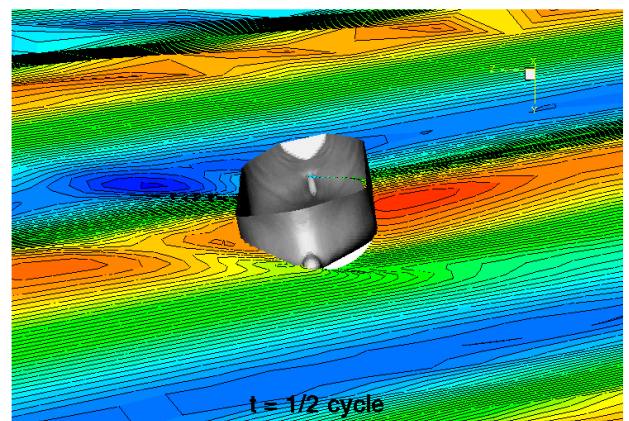
We can also organize and manage large aerodynamic, or aero-related hydrodynamic, research programs and design projects for example on America's Cup and Whitbread campaigns.



... applied to steady free-surface flows ...



... and to unsteady free-surface flows



Ten Years of Steady Flow Free-Surface Applications

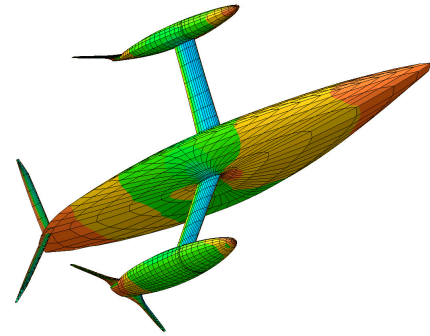
Double-Body IACC Yacht, Modelled as an Aircraft

SPLASH's underlying aerodynamic methodology

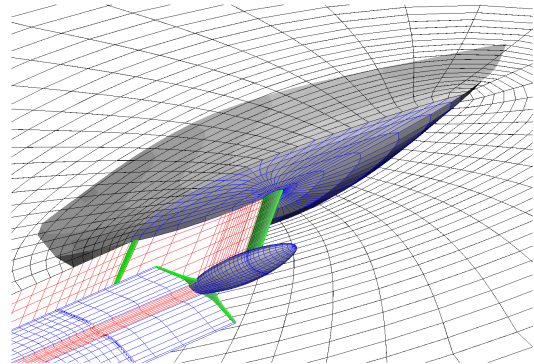
- fully generalized 3-D capabilities, for flexibility to treat a wide range of complex geometries and flows
- fluid motion governed by Laplace's equation for inviscid, incompressible, potential flow
- all surfaces modelled using rectangular arrays of quadrilateral panels, simple network panel and corner point data structure
- flow is generated by constant-source and constant-doublet surface singularities distributed over each panel
- zero normal velocity and extremely robust, internal zero perturbation boundary conditions, to set source strengths and to generate linear matrix solution for doublet strengths
- choice of direct or highly efficient block-iterative matrix solvers
- alternate boundary conditions for simulating: tab, rudder or other device deflection; boundary layer displacement; flow through surfaces such as inlets and exhausts; separated base flow
- for wakes, doublet-only panels model finite portion of trailing vortex system shed by lifting surfaces or base separations; Kutta condition at trailing edge; handles coplanar lifting-surfaces
- final velocities (and pressures) given by local source strength and panel-to-panel gradient of doublet strength
- in panel-to-panel doublet gradients, differencing across wakes accounts for discontinuities in potential and avoids early stencil termination, to retain high numerical accuracy in all flow regions
- panel pressure integration for force and moment predictions
- wake integration for alternate lift and induced drag estimates

Supporting package automates panelization, sink-and-trim, nonlinear free-surface features

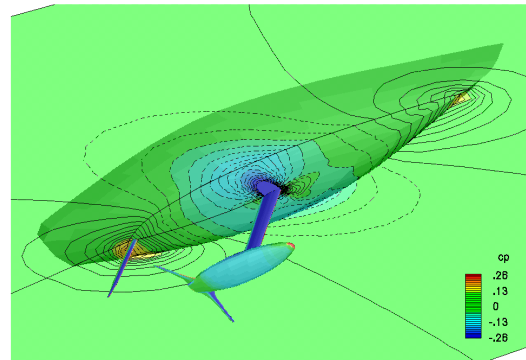
- one-time setup of geometric database, e.g., at design waterline
- controls panel model parameters, flow conditions; creates SPLASH input data set and job execution control files
- treats isolated ship hulls and yachts with hull, keel, bulb, wing and rudder components, including tab and rudder deflections
- full heel and yaw, sink and trim capabilities
- pebble-in-pond panelization of free-surface
- keel and rudder wake models follow hull and bulb slender body theory streamline traces
- stand-alone operation, or interactive operation with SPLASH, for free to sink-and-trim and nonlinear free-surface solutions
- nonlinear hydrostatics and waterline intersection computations
- crew weight and empirical user-specified sail force models
- free-surface updating and smoothing algorithms to suppress bow spray, rooster tail and other highly nonlinear behavior
- algebraic and elliptic-equation grid generation procedures
- automated detection of convergence for sink, trim and nonlinear free-surface shape
- updates summary files for post-processing of results, including wetted areas and lengths for viscous stripping



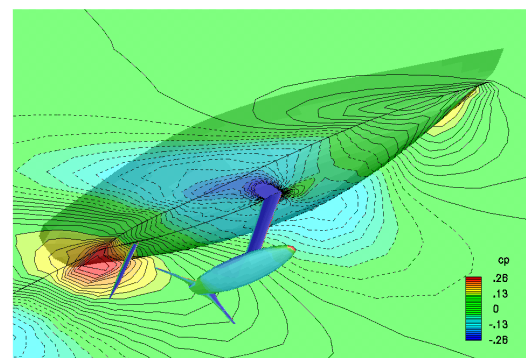
Free-Surface Panel Model for IACC Yacht



Steady Solution for Flat Free-Surface
Recreates Double-Body Flow Pressures

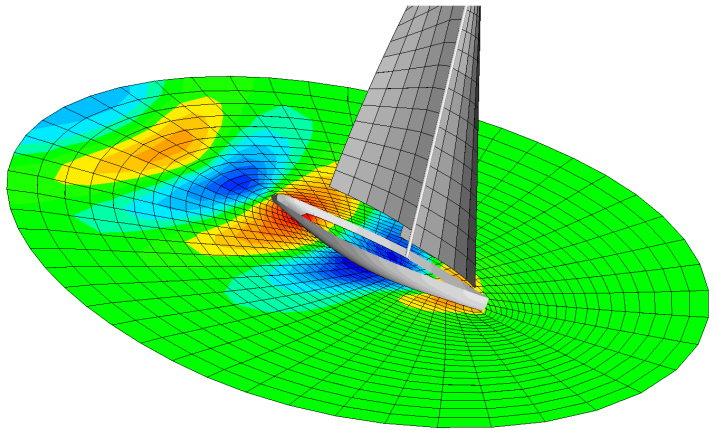


Pressures with Nonlinear Free-Surface Waves



SPLASH Steady Flow Free-Surface Capabilities

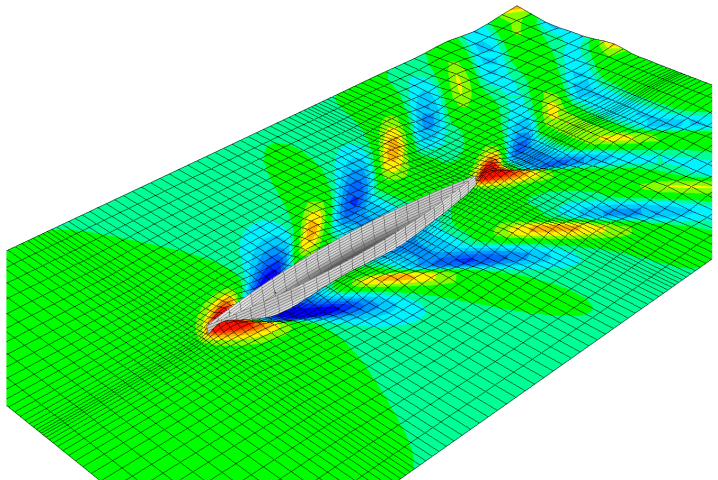
***"Pebble-in-Pond" Free-Surface Panelization
IACC Yacht***



Unique hydrodynamic free-surface methodology

- flexibility for a variety of model/free-surface topologies
- fully 3-D, fully interacting, simultaneous solution of free-surface wave and underwater "aerodynamic" flow fields
- zero pressure free-surface boundary condition, requires streamwise surface slope to balance streamwise gradient of hydrodynamic pressure
- free-surface flow is formulated as small linear perturbation to basis flow, this obtained first by treating all configuration and free-surface panels as solid and fixed
- high order, fully-upwinding/fully-rotating, finite difference stencil for streamwise pressure gradient contributions
- imposed on "other side" of free-surface with unique, robust, internal zero perturbation boundary condition formulation
- differencing across wakes, to ensure correct wave domain of dependence propagation characteristics in all flow regions
- reliable far-field wave radiation condition for outer boundaries
- input a flat free-surface, for classic double-body linearization of free-surface boundary conditions
- iteratively adjust model position, for free to sink and trim results
- iteratively drive panel corner points to computed wave elevations, for exact nonlinear solution of free-surface boundary conditions
- panel pressure integration for force and moment predictions

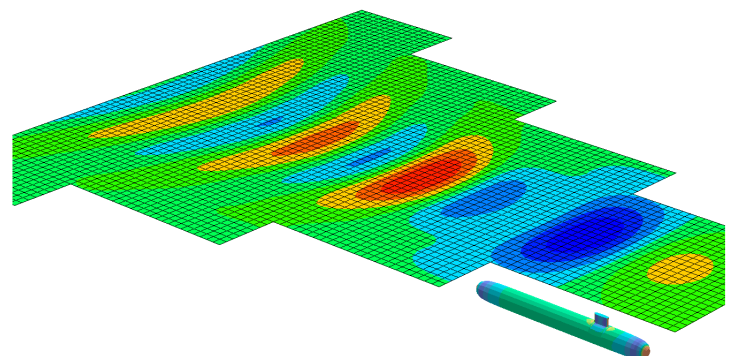
***Cartesian Free-Surface Panelization
Wigley Research Hull***



Useful features and general information

- detailed output of model and flow data, sectional loads, component and total configuration forces and moments
- output of flow visualization file in Tecplot format
- y and z symmetry options, for half-model, finite-depth, other special simulation capabilities
- high accuracy off-body velocity scans
- automated panel abutment and wake shedding search algorithms to assist with custom model development
- "restarts" to minimize multiple configuration run times
- translators available to extract configuration geometric database meshes from IGES and FastYacht-IDF format NURBS surfaces, for input to supporting automated panelization package and SPLASH
- post-processing software tabulates results, with optional viscous stripping of database meshes, including computed nonlinear wetted area and wetted length variations
- use on UNIX platforms
- single SPLASH iteration run time is on the order of a minute on a CRAY YMP, a few minutes on workstations
- full numerical tank test (fully appended yacht, 80 point test matrix, nonlinear free-surface, free to sink and trim) in 3-5 hours on a CRAY YMP, half a day on workstations

***Patched Cartesian Free-Surface Panelization
Generic Submarine***



America's Cup 1987

A history of success

SPLASH was originally developed to assist yacht designers during Dennis Conner's 1987 challenge to regain the America's Cup. SPLASH computational design studies proved crucial to the design of *Stars and Stripes '87*, the winner of the most exciting and hotly contested races in America's Cup history, sailed in Perth, Australia.

Unsurpassed accuracy

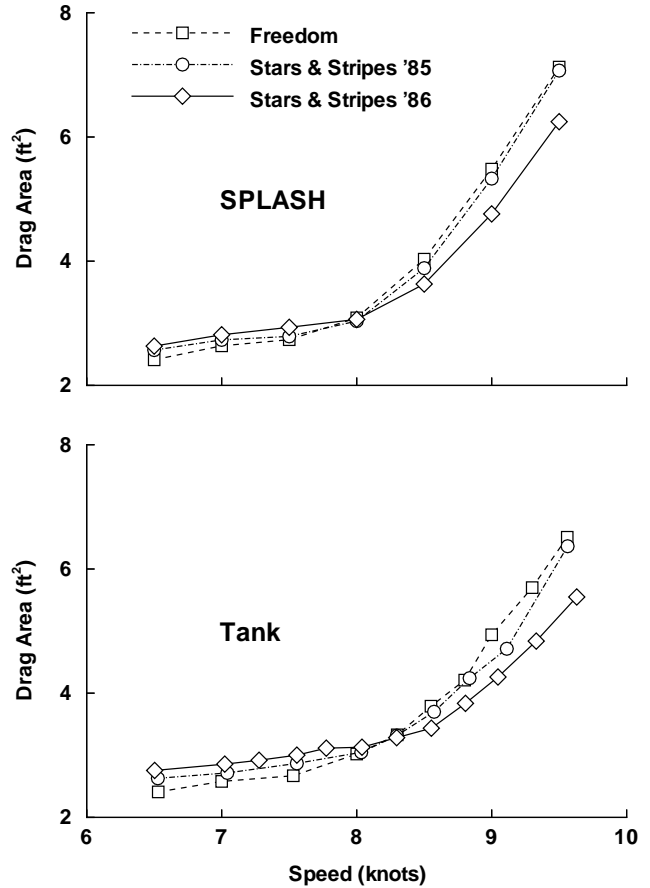
Although crude by today's standards, these early SPLASH calculations represented a major breakthrough in free-surface flow simulation technology. Prediction of upright wave resistance was remarkable, on an absolute basis, and on a boat-to-boat basis. The accuracy of even these early results remains unsurpassed. With SPLASH's ability to also treat arbitrary geometries and lifting surfaces, designers were for the first time able to use computer-based flow simulations to study the 12-metre yachts at actual sailing conditions.

Design-driven solutions

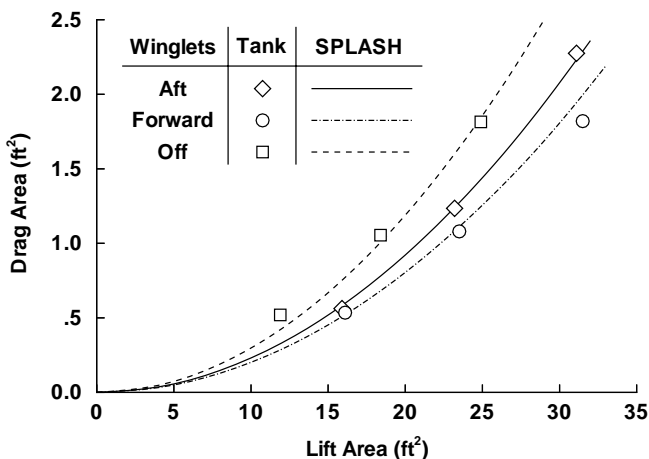
The relatively heavy and non-wall-sided hull form, and low aspect ratio keel and wings, introduce strong free-surface wave effects. SPLASH-based design and analysis studies were used to:

- validate towing tank and full scale test data concerning the effect of hull shape (e.g. length, prismatic coefficient, area distribution, section shape) on wave drag, upright and heeled
- predict appendage wave drag contributions
- optimize keel and winglet planforms for minimum lift-induced drag (due to side-force) in the presence of the free-surface
- determine winglet incidence, twist and camber in the presence of strong free-surface flow angularity, while minimizing interference with hull and keel components.

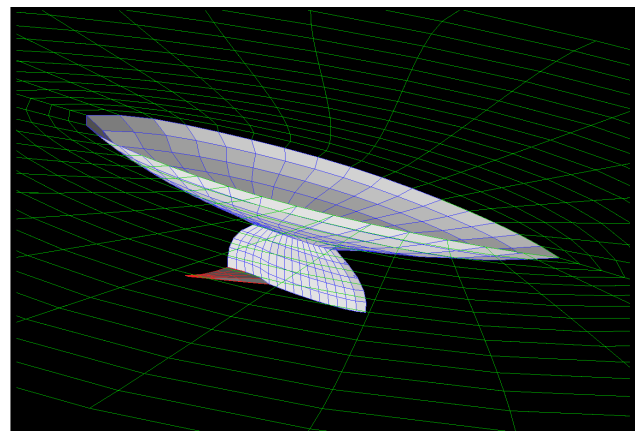
3-Boat Total Upright Resistance Comparison



Australia II Winglet Variations Induced Drag Comparison



Free-Surface Panel Model Stars & Stripes '87

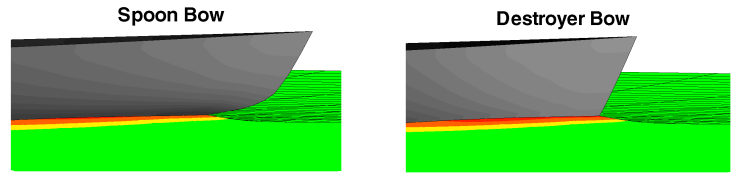
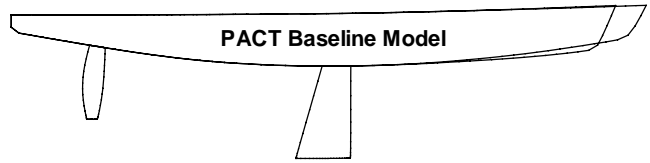


America's Cup 1992

Nonlinear free-surface captures difference between spoon bow and destroyer bow

Upright wave resistance is higher for a destroyer bow than for a spoon bow, as determined from PACT tank tests. SPLASH nonlinear free-surface solutions correctly predict this trend. The corresponding linear free-surface solutions do not.

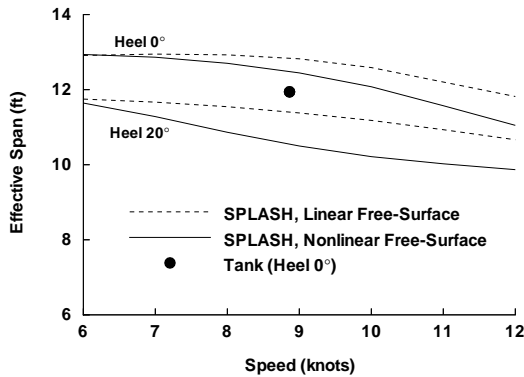
Sink and trim are predicted with high accuracy, and strongly affect drag. A wealth of highly accurate design information is made available, for example viscous wetted area skin friction drag, or the effect of crew location, as well as usual upright wave resistance and lift and induced drag values.



Nonlinear free-surface enhances prediction of forward speed effect on lift induced drag levels

Effective span measures how efficiently lift is generated. Smaller effective spans mean higher lift-induced drag levels. Compared to linear free-surface predictions, SPLASH nonlinear results show a much greater reduction in effective span as boat speed, and free-surface effects, increase.

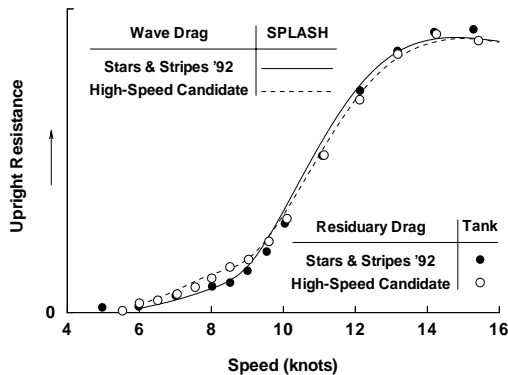
Impact of Nonlinear Free-Surface on Effective Span



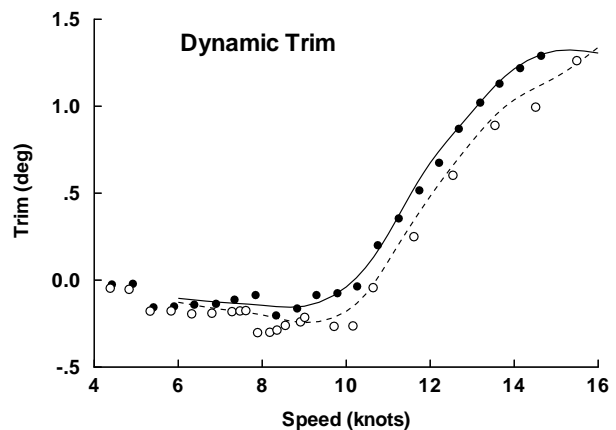
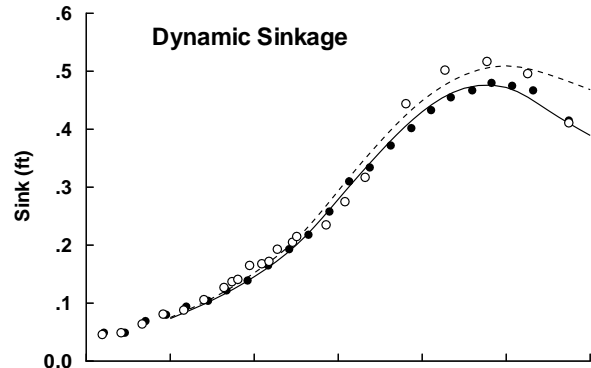
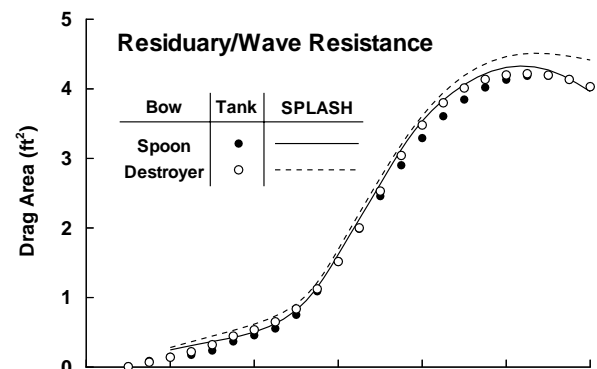
SPLASH confirms Team Dennis Conner tank data, outperforms other numerical design tool

Team Dennis Conner requested calculations for several hull variations. Blind SPLASH predictions, made with no prior knowledge of tank data, agreed with the tank for all variations considered. This work was featured in a paper presented at the 1993 Chesapeake Sailing Yacht Symposium.

Unexpected Low Speed Penalty for "Optimized" Hull



PACT Spoon Bow/Destroyer Bow Comparison



America's Cup 1995

SPLASH used in design of *Young America*

South Bay Simulations has strong relationships with other highly qualified individuals and organizations in the aerospace and marine industries. And although we worked primarily for 1995 America's Cup challengers, we directly contributed our support to the U.S. defense.

Joe Laiosa, of Fluid Motion Analysis Consulting, used SPLASH under a cooperative agreement to assist PACT 95 in its hull and appendage design efforts. The end result is best illustrated by this statement, made upon the selection of PACT's boat for the 1995 defense of the Cup:

"Four months of defender trials have proven Young America's hull speed advantages"

Dennis Conner

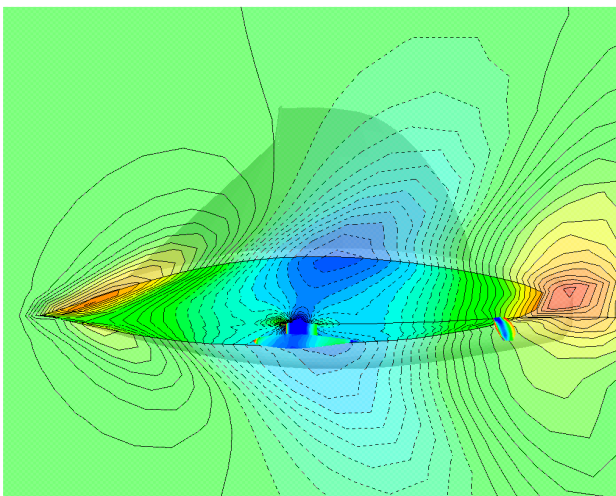
Hull and appendage wave drag prediction

PACT 95 researchers and designers were fully aware from previous America's Cup campaigns of SPLASH capabilities. In fact several portions of PACT's VPP are based on SPLASH-derived data. For '95, they chose to "SPLASH" roughly 20 hull forms in the computer, and to test about 5 hulls in the towing tank.

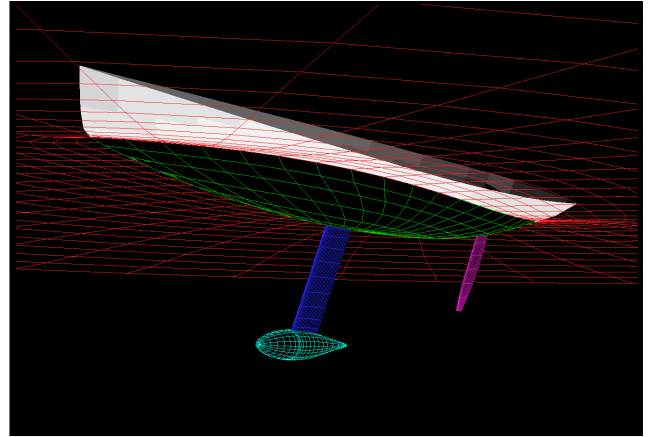
For the design of *Young America's* hull and her fin/bulb appendages, calm-water wave drag and hull viscous wetted area were based upon SPLASH predictions. VPP's relied on a mixture of tank data and SPLASH results for maximum design impact.

Extracting wave resistance from tank tests can be difficult. Drag of studs for turbulence stimulation, hull and appendage skin friction and form factors levels, and wetted areas and lengths are all required. These are usually measured, derived from special tank tests, or empirically estimated. SPLASH predictions are highly accurate not only for wave drag, but also for hull wetted areas and lengths. Using this information leads to greater accuracy, both in numerical predictions, and in analysis of data from the towing tank.

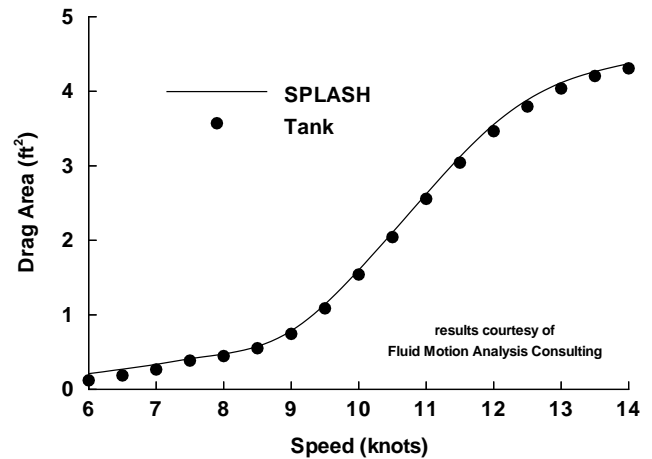
Pressure Contours at Heel and Yaw



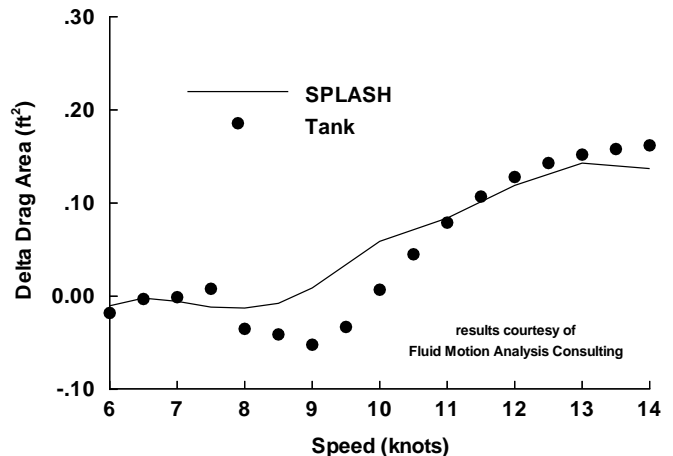
Panel Model at Heel and Yaw



Yacht Upright Wave Resistance Comparison PACT Baseline Fin/Bulb Model



Bulb Contribution to Upright Wave Resistance PACT Baseline Fin/Bulb Model



IACC Hull Design: Australian Entries, 1995 America's Cup

SPLASH operates as numerical towing tank

Although her days were numbered, the yacht *oneAustralia-2* gave Team New Zealand its toughest competition. The Australian hull shape was the culmination of a multi-year design program. In the light winds off San Diego, she was noticeably faster than her predecessor, *oneAustralia-1*. This speed advantage had been predicted in the towing tank, and even more so in the computer, using SPLASH.

Turnkey operation of SPLASH was established early in the Australian effort, providing the designers with a numerical towing tank. Roughly 100 designs were SPLASH'd, while only about 20 hull shapes were tank tested.

For each candidate hull form and standard appendage package, nonlinear free-surface results were computed over a standard 70-point matrix of heel/speed/yaw combinations. With six degree-of-freedom forces and moments obtained for a wide range of sailing conditions, SPLASH-based VPP analyses could be generated without resorting to linear theory approximations such as lift curve slope and effective span. Computed wetted areas and lengths were also used, to extract viscous drag and form factors from tank data, and to build up full-scale viscous drag estimates.

Added resistance in waves, at heel and yaw, was also computed at three representative upwind sailing conditions, over a range of incident wave lengths. Both calm and rough water VPP analyses resulted.

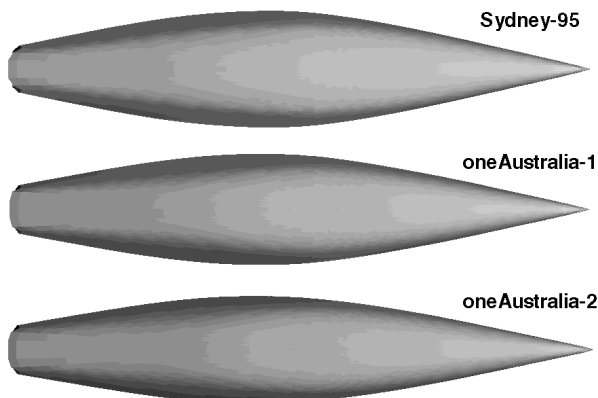
The towing tank yielded similar information, and VPP's provided the tank's own view of relative yacht performance. SPLASH-based VPP's were anchored to baseline tank data, using SPLASH to predict boat-to-boat differences only, for as much realism as possible.

Design team satisfaction and confidence with SPLASH prompted one famous Australian team member to comment:

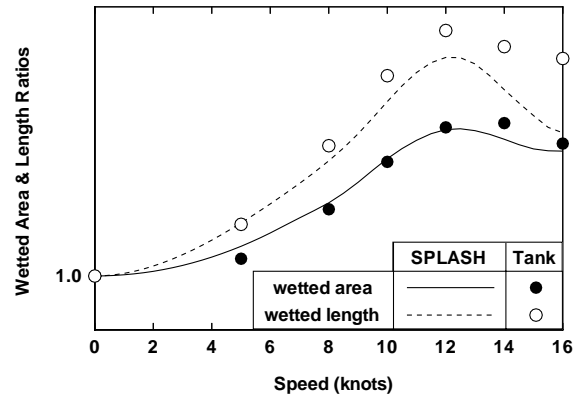
"This stuff is just fantastic"

John Bertrand

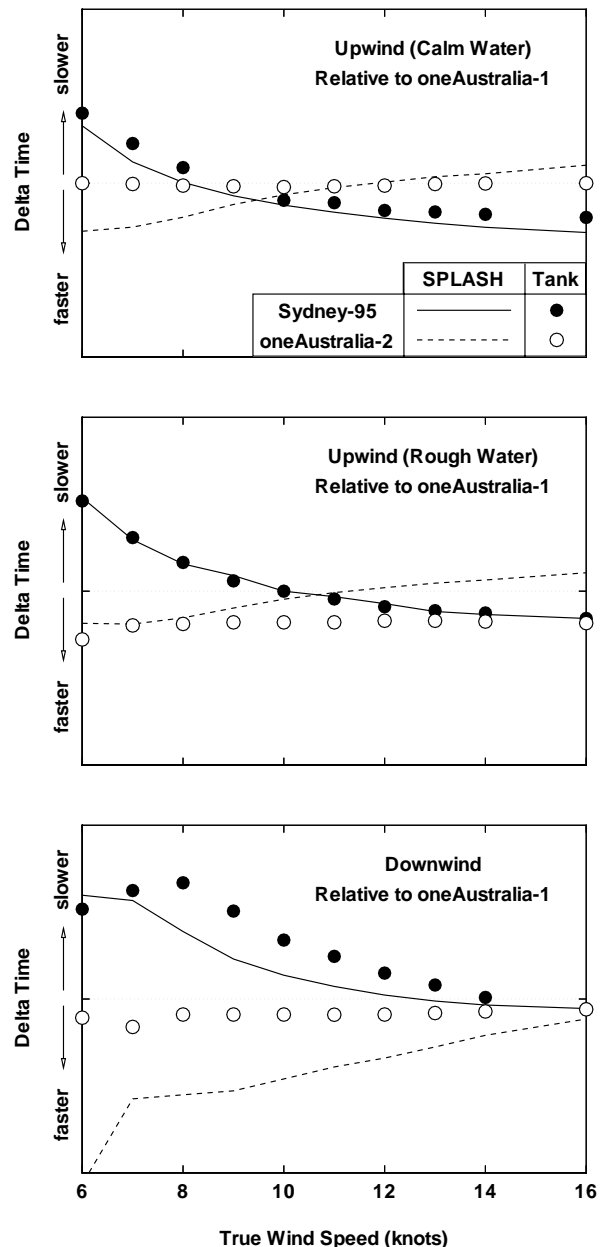
IACC Hull Variations



Hull Wetted Areas and Lengths Sydney-95



VPP Course Leg Times IACC Hull Variations



IACC Appendage Design: Australian Entries, 1995 America's Cup

Use SPLASH to assess appendage performance tradeoffs

Appendage performance is an integral part of yacht design. For racing yachts it is one of the main areas to study for improving overall performance.

SPLASH's automated panelization package can handle a variety of standard appendage geometries:

- keel
- keel with blended bulb
- keel with tip-mounted bulb
- keel with tip-mounted bulb and bulb-mounted wing
- rudder
- simulation of keel-tab and rudder deflection

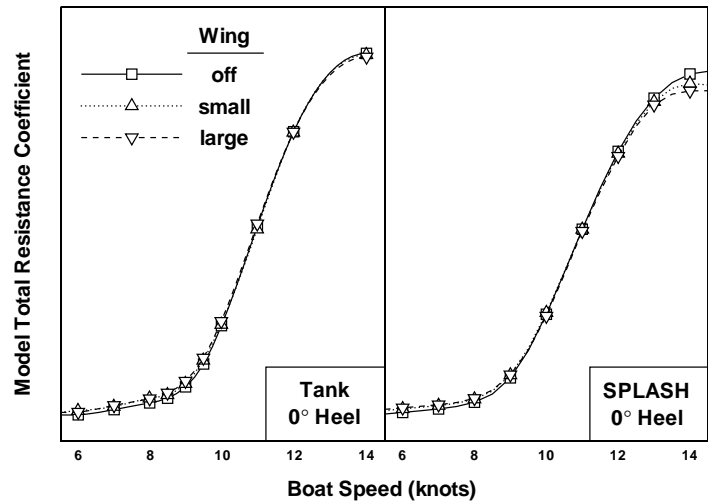
SPLASH delivers reliable and accurate predictions for all three major contributions to appendage drag:

- wave drag
- lift-induced vortex drag, due to generation of side force
- viscous drag, estimated using stripping techniques incorporated into automated post-processing software

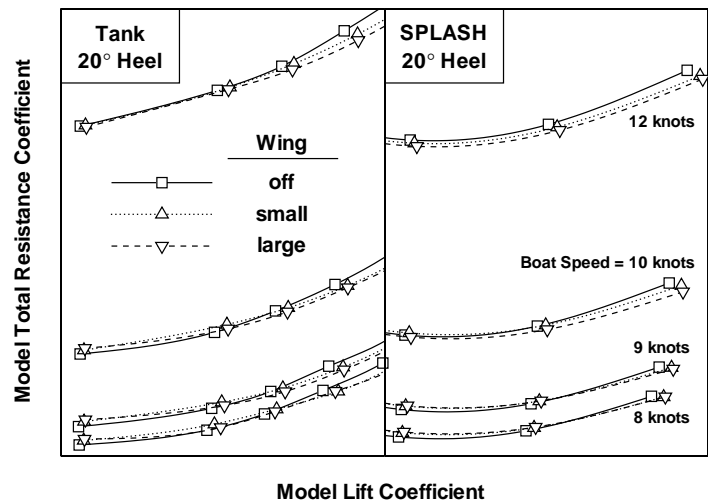
SPLASH panelization and flow simulation capabilities deliver information required for sensitive design studies such as:

- impact of foil size/planform/thickness on section and span load, total drag, yacht balance, stability and control
- optimization of bulb volume and shape characteristics (length, thickness, squash, area distribution, nose and tail)
- optimization of wing incidence, camber, twist
- local flow analysis for detail shaping, to avoid severe flow gradients, or to minimize component and juncture interference effects
- free-surface wave effect on lift and induced drag, and appendage contributions to wave drag
- enhanced analysis of model and full-scale test data, using computed wetted areas and lengths; assessment of tank viscous drag-due-to-lift levels

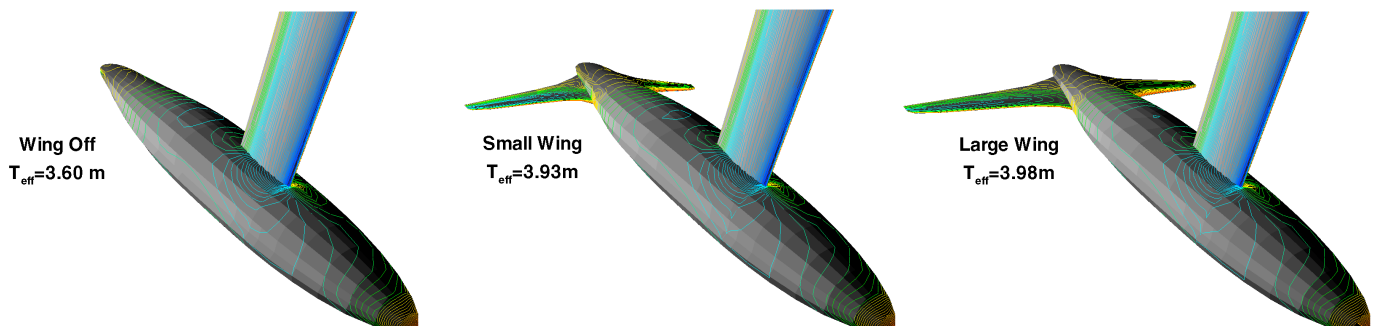
Upright Resistance Compared to Raw Tank Data oneAustralia-2



Drag Polars Compared to Raw Tank Data oneAustralia-2



SPLASH Appendage Models with Computed Pressure Contours oneAustralia-2



IMS Yacht Design Applications and Rule Development Studies

For IMS applications, SPLASH provides a wealth of information and high accuracy at low cost

Naval architects and yacht designers worldwide are using SPLASH software and consulting services to better test their designs against the IMS rule. If you're already testing in the tank, rely on SPLASH as well, to reduce overall costs, and to deliver detailed flow and performance-related data not easily measured in the tank (e.g., appendage spanload distribution, bulb surface pressures). If you don't normally tank test, due to cost or other factors, SPLASH predictions may be just what you need to improve your designs.

Riechel/Pugh IMS yacht hull forms optimized using SPLASH-based VPP's

The R/P IMS 66' *Exile* and new R/P IMS 80' *Morning Glory* were designed testing single baseline configurations in the tank and SPLASH'ing candidate variations for VPP comparisons. Jim Pugh discusses *Exile*, and SPLASH, in the May '95 issue of *Seahorse* magazine.

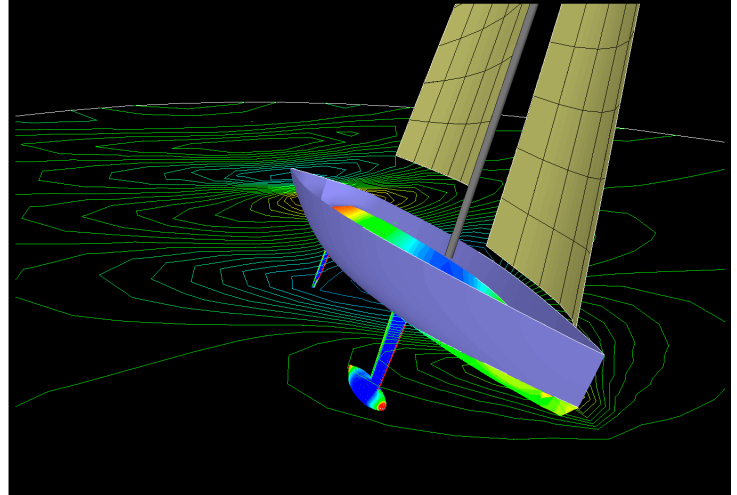
<i>EXILE</i> 's track record:	<u>Place</u>
• 1995 Long Beach Race Week IMS Class	1st
• 1995 Big Boat Series City of San Francisco Perpetual Trophy IMS Maxi Class	1st
• 1995 Tranpac IMS Class	1st
• 1995 Newport to Cabo Race IMS Class	1st
• 1994 Sydney to Hobart Race IMS Class	3rd

IMS Committee relies on SPLASH for rule development and enhancement

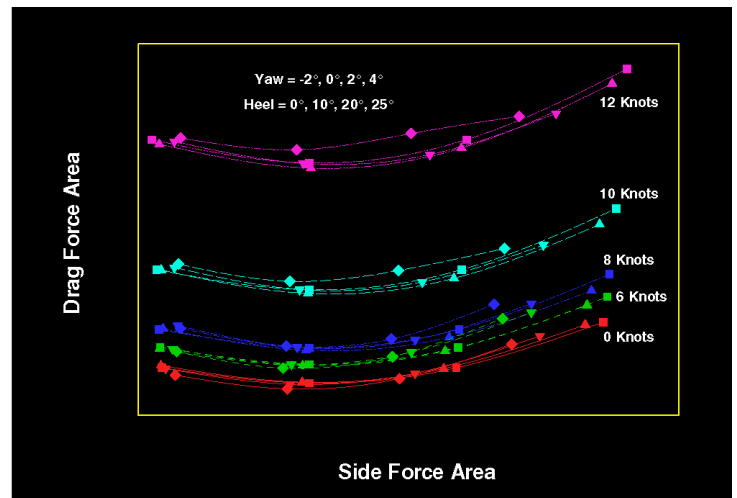
Special SPLASH keel and bulb wave drag studies are described in "Appendage Drag in the IMS Rule," by Jim Teeters, in the Oct '95 issue of *Seahorse* magazine.

The IMS Committee now plans to support SPLASH studies, in conjunction with tank tests, to supply performance data for hull forms more representative of the current fleet.

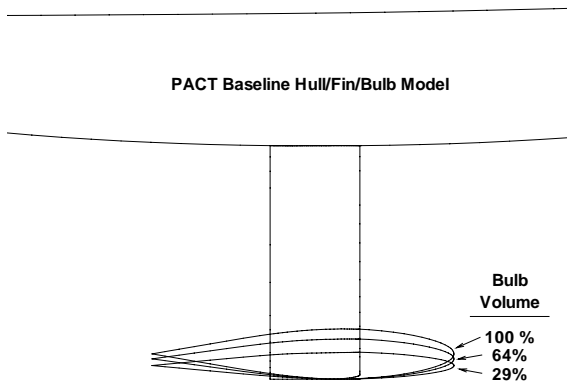
SPLASH Flow Simulation for Morning Glory Reichel/Pugh 80Ft IMS Race Yacht



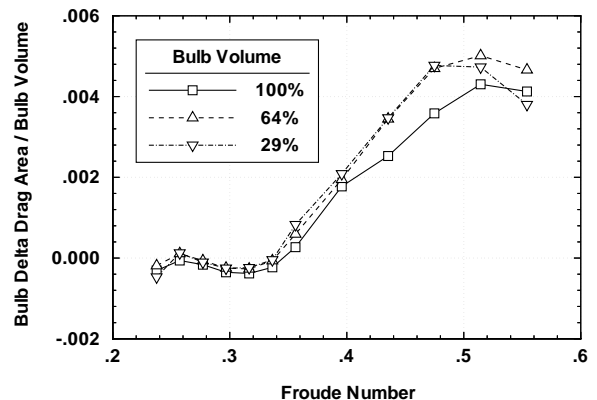
Complete SPLASH Drag Polar Matrix with Viscous Stripping Candidate Morning Glory Model



PACT IACC Bulb Variations IMS Appendage Wave Drag Study



SPLASH Bulb Contribution to Wave Drag Nondimensionalized by Bulb Volume

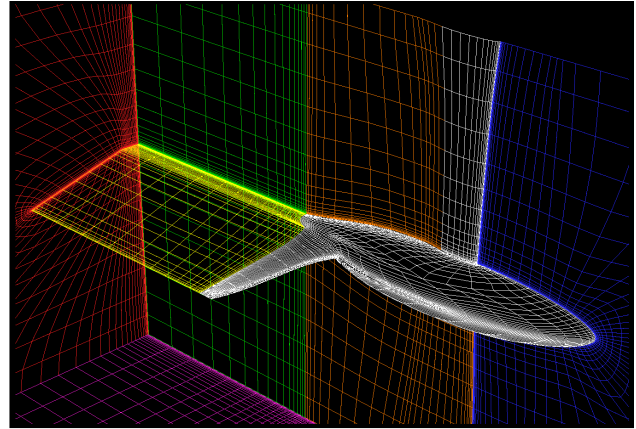


Expertise in Aerodynamic and Hydrodynamic Design and Analysis

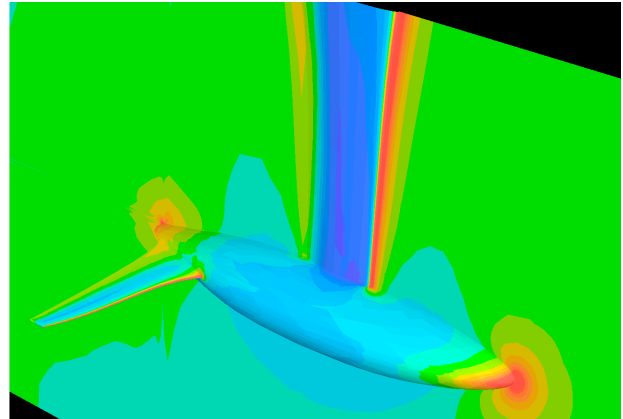
Our expertise goes beyond SPLASH software and services:

- in-depth understanding of basic aerodynamic and hydrodynamic principles governing vehicle performance, stability and control
- familiarity with conventional, analytical and semi-empirical, design and analysis methodologies
- experience with, and access to, the major types of numerical methods in use today for prediction of vehicle characteristics
- state-of-the-art viscous flow simulation capabilities for advanced aerodynamic studies:
 - airfoil section characteristics
 - flow quality and performance predictions for isolated hull and appendage components
 - design and analysis of integrated appendage packages
- we are uniquely qualified to develop approaches for studying very complex marine-related flows, for example:
 - viscous free-surface flow
 - sail 3-D viscous analysis
- on large projects, organization/management of related resources:
 - overall responsibility for aerodynamic, or aero-related hydrodynamic, research programs and design projects
 - identification of key design personnel and liaison with world-renowned experts in related areas
 - selection of computer resources
 - overseeing of wind tunnel test programs

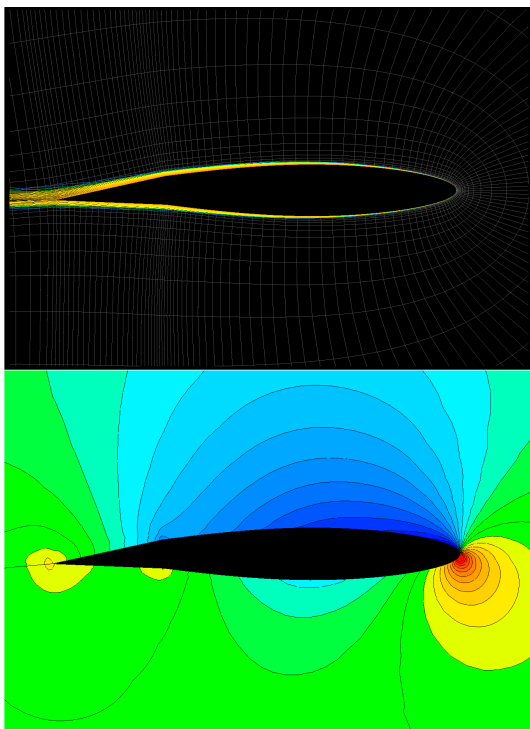
**Multi-Block Viscous Mesh
oneAustralia Fin/Bulb/Wing**



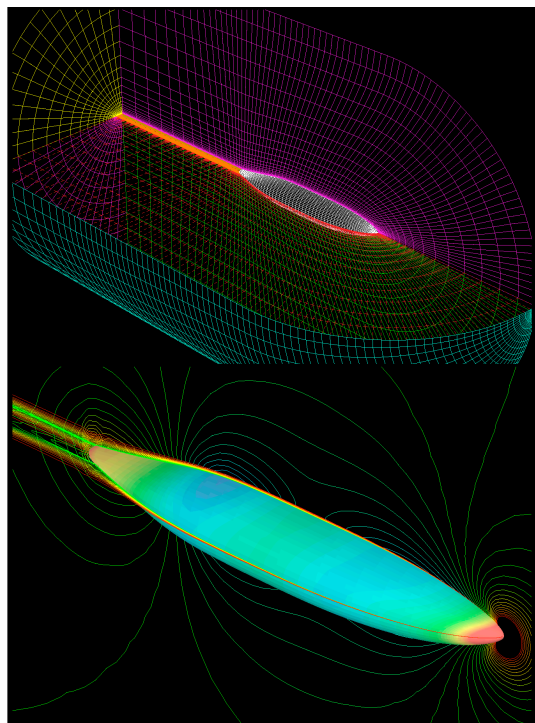
**Static Pressure Contours
oneAustralia Fin/Bulb/Wing**



**Viscous Mesh, Total and Static Pressures
oneAustralia Keel Section with Tab**



**Viscous Mesh, Total and Static Pressures
oneAustralia Bulb**



Wave Field Predictions Capture Details with Astounding Accuracy

Free-Surface Wave Elevations QUAPAW Fleet Tug Boat ($Fr=0.32$)

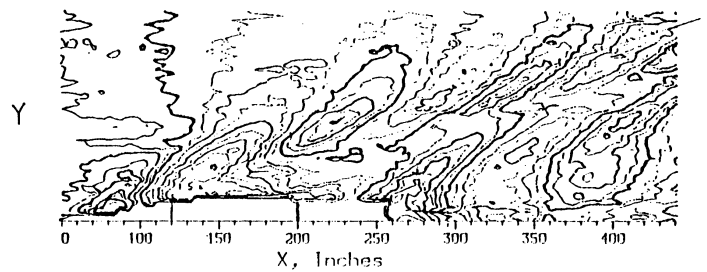
SPLASH ranked #1 in wave field accuracy

For surface-piercing ships and yachts, "pebble-in-pond" free-surface panelization is typically employed. Circular grids maintain high resolution near the model, and can treat a wide range of hull form and flow parameters. They are easily coarsened as they move away from the ship, to better capture the double-body "endplate" effect of the free-surface. Dissipation of waves as they propagate downstream, onto the coarser mesh, is unimportant for most applications.

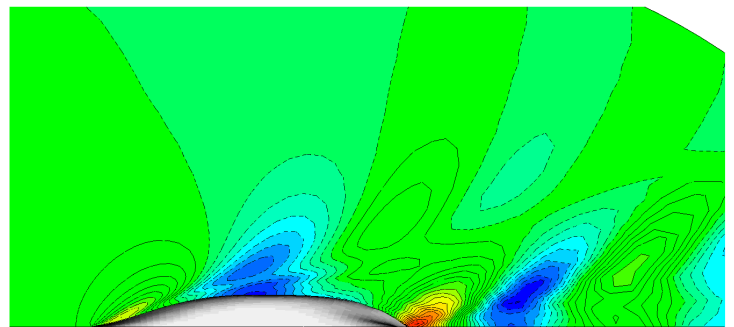
Nevertheless, pebble-in-pond panelizations enabled SPLASH linear free-surface Kelvin wake predictions for the QUAPAW fleet tug boat, as part of the David Taylor Research Center "Wake-Off" wave pattern numerical prediction and evaluation study. In the final report (DTRC/SHD-1260-01), researchers W.T. Lindenmuth, T.J. Ratcliffe and A.M. Reed state that SPLASH

" ... gave the best predictions of all for the details of the free-surface disturbance in the region within one ship's beam of the model. These predictions showed free-surface details (evident in experiments) which were, at best, hinted at by the predictions from the better of the other programs."

Scale Model Test (David Taylor Research Center)



SPLASH



Patched Cartesian grids provide high grid densities for Kelvin wake predictions

In SPLASH, as expected, accurate propagation of waves over large distances requires high grid densities and lots of panels.

Other approaches are available which are not restricted in this fashion, for example Havleock source methods. But simplifying approximations ultimately compromise what can be expected from these other approaches. Hybrid methods offer some promise but are still largely unproven, and none offer SPLASH's basic near-field accuracy.

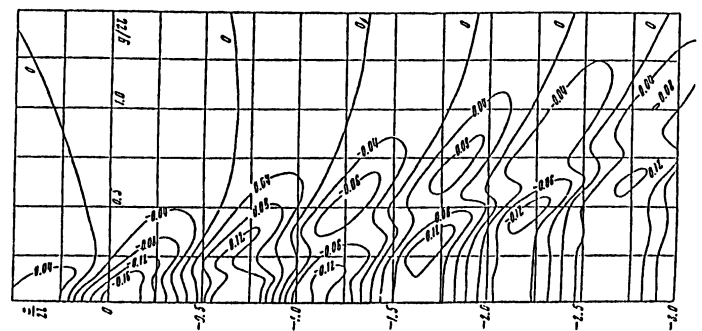
The automated geometry and panelization support package, as currently available, generates only pebble-in-pond free-surface models. But SPLASH itself is fully generalized to treat a wide range of configuration and free-surface topologies. So one-of-a-kind panel models can be generated that may be better suited to the problem at hand.

One example is the prediction of flows and wave patterns induced by submerged bodies. In the absence of any waterline intersection, patched Cartesian grids are easily utilized to optimize free-surface panelization.

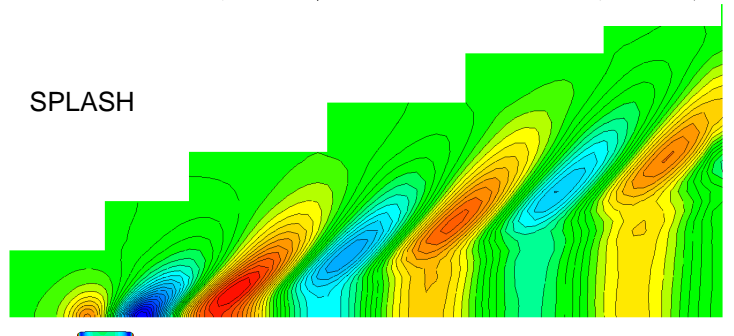
Depending on computer resources, larger numbers of panels can be used, to capture results farther downstream. SPLASH's efficient iterative matrix solvers help make problems with large numbers of panel more tractable. Far-field wave radiation conditions at upstream, downstream, and side boundaries are also generalized for ease of use.

Free-Surface Waves Elevations Submerged Ellipsoid ($Fr=0.75$)

Numerical Solution, Source/Sink Pair (origin unknown)



SPLASH



Design and Analysis for Submerged Vehicles, as well as Ships and Yachts

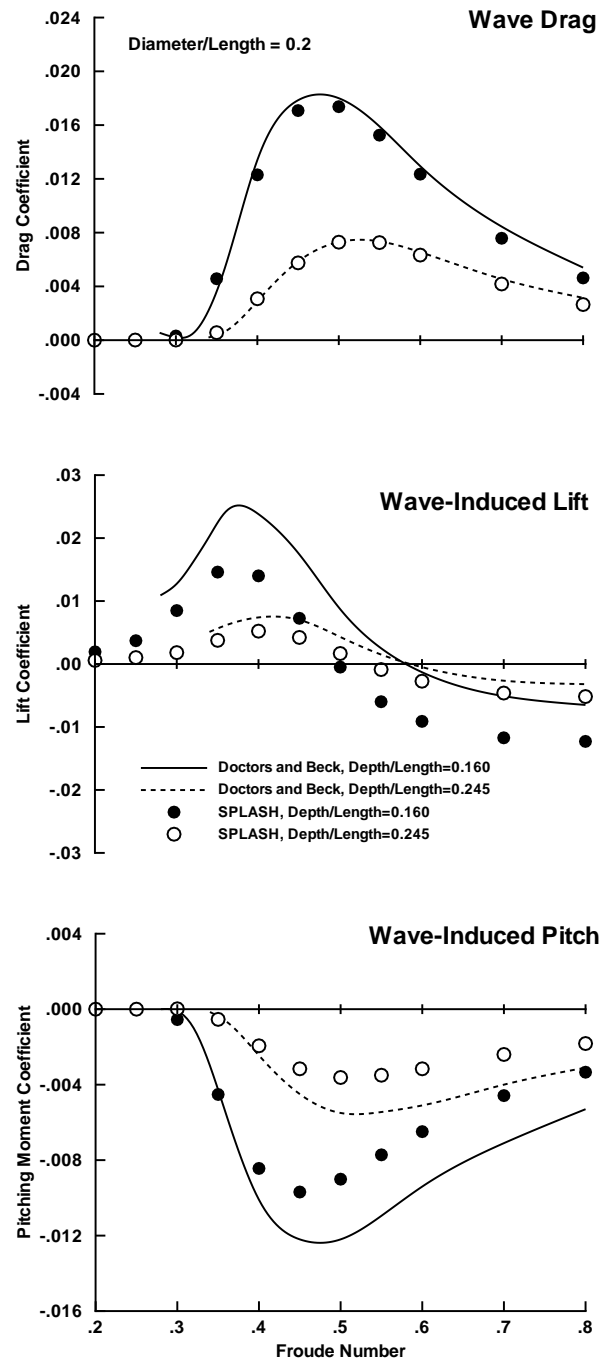
Wave-Induced Forces and Moments Submerged Ellipsoid

High accuracy under, as well as on, the water

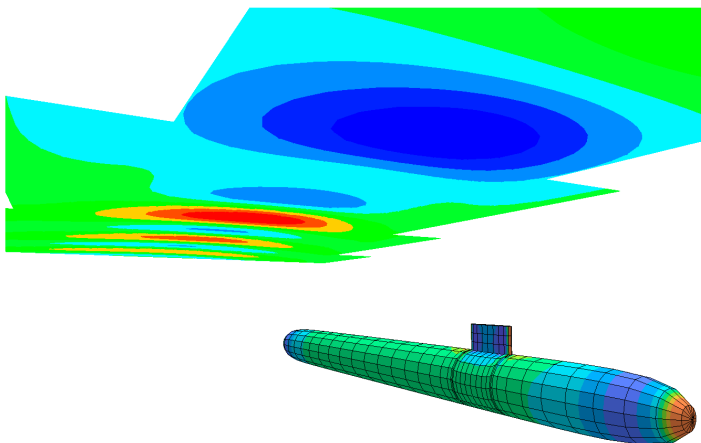
Accurate treatment of the free-surface, coupled with the ability to handle complex realistic configurations, makes SPLASH a natural choice for studying submerged vehicle characteristics.

Wave-induced force and moment predictions for a submerged ellipsoid show good agreement with other numerical analysis methods. Free-surface signatures are also captured, to varying degrees, this determined by free-surface panel densities.

One area which remains unexplored is the use of SPLASH to study nonlinear wave effects for vehicles in very close proximity to the surface. For these cases, SPLASH can be expected to perform well, at least up to the point where wave breaking occurs or the vehicle broaches the surface.



Hull and Free-Surface Pressures Generic Submarine



Model complex submerged vehicle geometries

Panel model generation is simplified by the use of Cartesian free-surface grids. The fairly rounded hull forms typical of most submersibles are easy to panel, and appendages such as conning tower or rudder control surfaces can also be included.

Seakeeping: Wigley Research Hull

New SPLASH unsteady capability

For ships and yachts, using a 3-D flow method to compute motions and added resistance in waves is one of the world's most challenging problems. Testing in waves in the tank is also difficult, expensive and subject to large uncertainties, requiring much expertise to collect meaningful data.

Our success with SPLASH for steady flows therefore left users inquiring about a similar capability for unsteady flows. They knew that achieving SPLASH steady flow prediction accuracy for the unsteady problem would be a major step forward in technology. We are happy to announce that this capability is now available and lives up to expectations.

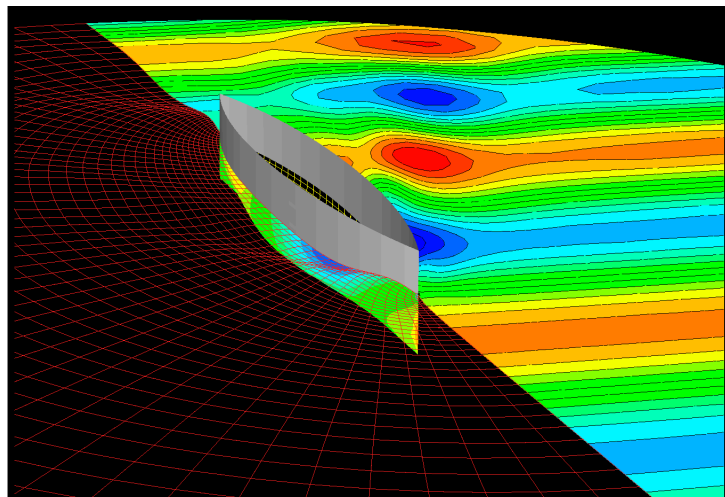
The new SPLASH unsteady capability displays accuracy levels similar to those for steady flows. Not surprising, since the unsteady flows are solved using the same techniques as for steady flows, merely extended to the complex frequency domain. So all the years of research, development and engineering experience treating steady flows are reflected in the new unsteady capability.

Users of numerical methods will appreciate that SPLASH unsteady results, like those for steady flows, are based on panel pressure summation. This means that all forces and moments are obtained by integrating the locally computed pressures over all of the panels making up the vessel. Unsteady forces and moments also include a panel-based waterline integral contribution, essential for computing second-order forces such as added resistance.

Many other methods use a far-field approach for computing added resistance, because local flow details are not properly captured, in which case local panel pressure integration is known to yield poor and unreliable results. We believe that the success of the SPLASH unsteady capability, as based on panel pressure integration, is an indication that local flow details are indeed captured with the highest accuracy possible.

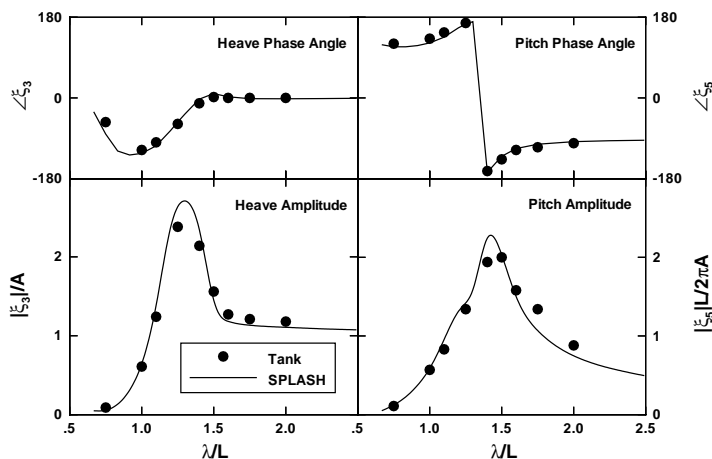
(Wigley hull unsteady tank data from Delft University)

Panel Model and Unsteady Pressure Contours

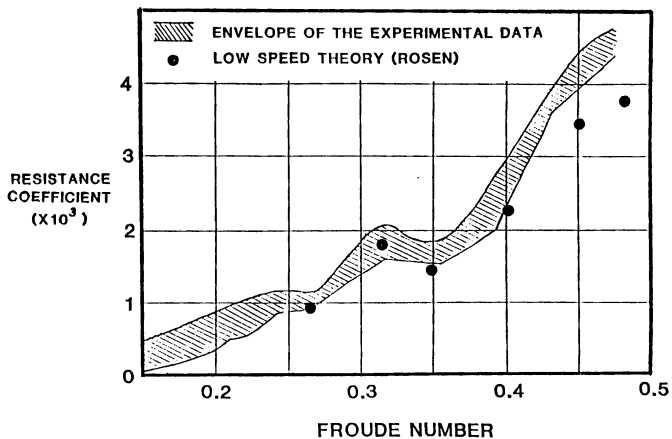


Unsteady Motions in Waves

Wigley Hull $C_m=0.909$, $L/B=10$, $B/T=1.6$ $Fr=0.3$ Head Seas

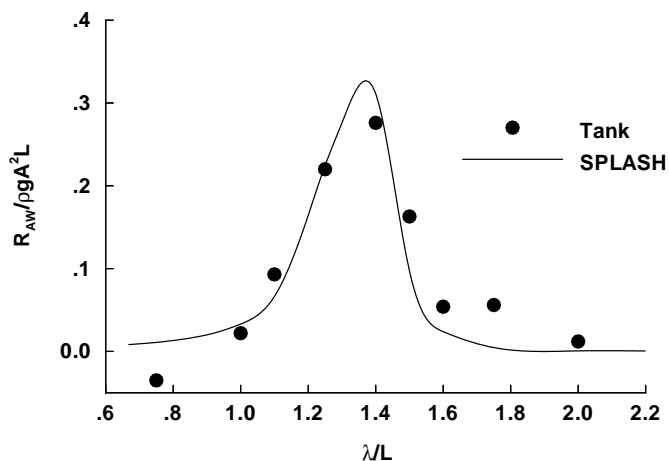


Steady Wave Resistance (circa 1986)



Added Resistance in Waves

Wigley Hull $C_m=0.909$, $L/B=10$, $B/T=1.6$ $Fr=0.3$ Head Seas



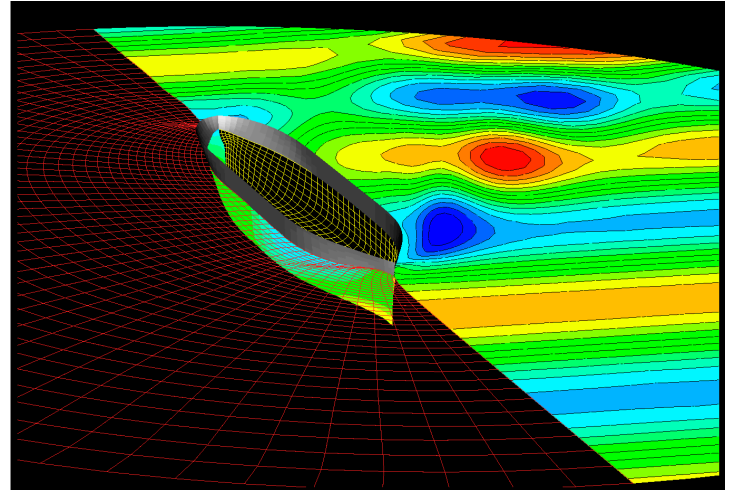
Seakeeping: Series 60 Hull

New SPLASH unsteady features

- unsteady flow computed using steady flow panel model
- unsteady flow and motions are linearized as small perturbations to steady basis flow
- steady basis flow can be either double-body (flat free-surface) or nonlinear (wavy free-surface)
- unsteady flow and motions oscillate harmonically, at frequency of encounter between ship and incident wave
- complex variable treatment of unsteady motions, potentials, panel source and doublet strengths, wakes, etc.
- rotating/upwind finite difference stencil of steady free-surface boundary condition also used for convective portion of unsteady free-surface boundary condition
- far-field wave radiation conditions to treat both high frequency (downstream propagating) and low frequency (upstream and downstream propagating) wave encounter
- separate solutions obtained for ship oscillating in calm water in each motion degree of freedom, plus for ship moving through waves but fixed ... linear superposition then provides final solution for ship free whilst moving through waves
- panel pressure integration, with waterline integral contributions, for first-order and second-order forces and moments; motions and added resistance predictions
- full 6 degree-of-freedom capabilities, including steady heel and yaw, and arbitrary incident wave heading
- symmetry option to treat upright steady cases in pure head/following seas, maximizes use of computer resources

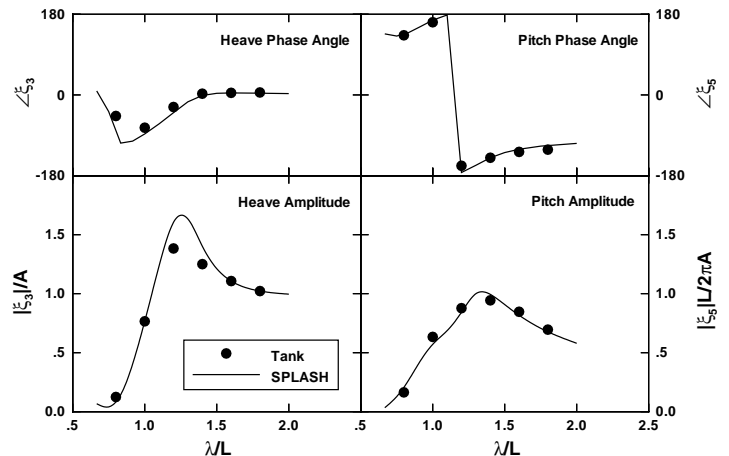
(Series 60 hull unsteady tank data from Delft University)

Panel Model and Unsteady Pressure Contours



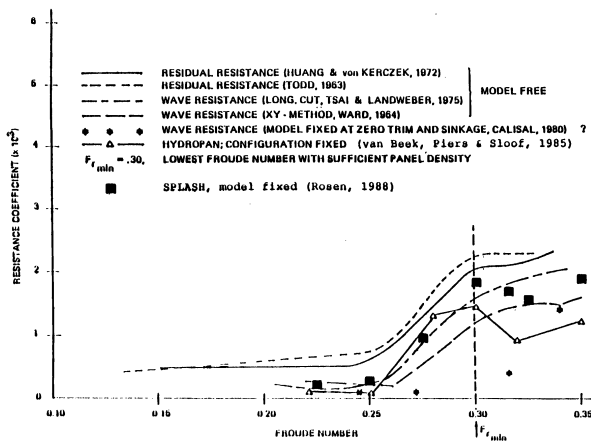
Unsteady Motions in Waves

Series-60 Hull $C_B=0.70$, $L/B=7.0$, $B/T=2.5$ $Fr=0.2$ Head Seas



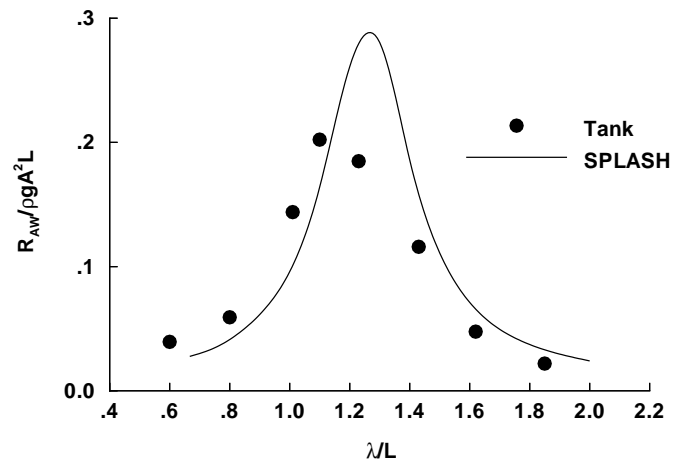
Steady Wave Resistance

(circa 1988, original figure source unknown)



Added Resistance in Waves

Series 60 Hull $C_B=0.70$, $L/B=7.0$, $B/T=2.5$ $Fr=0.2$ Head Seas



Seakeeping: 165,000 DWT Oil Tanker

Simulations so realistic they'll make you seasick

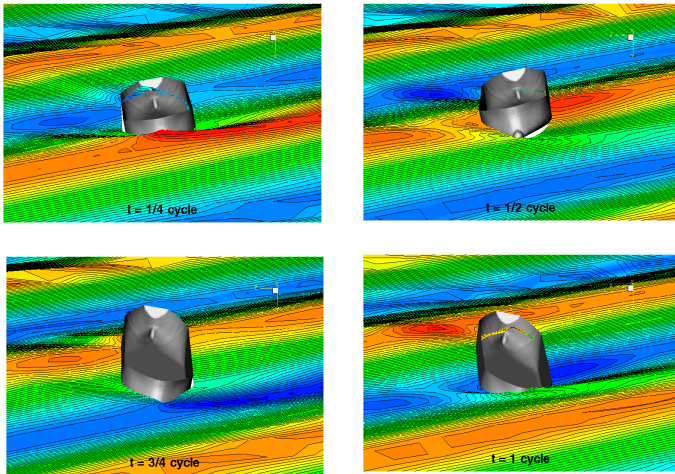
Ship structural analysis requires the state-of-the-art in several key technology areas. Detailed research and engineering efforts can be compromised by a lack of knowledge about detailed hydrodynamic loadings.

Ship structural analysis is about to take a giant leap forward. Calculations utilizing recent SPLASH unsteady code enhancements have validated results over the broad range of incident wave frequencies and heading angles of interest. And new tools have been developed to format SPLASH pressure output to facilitate input to structural models.

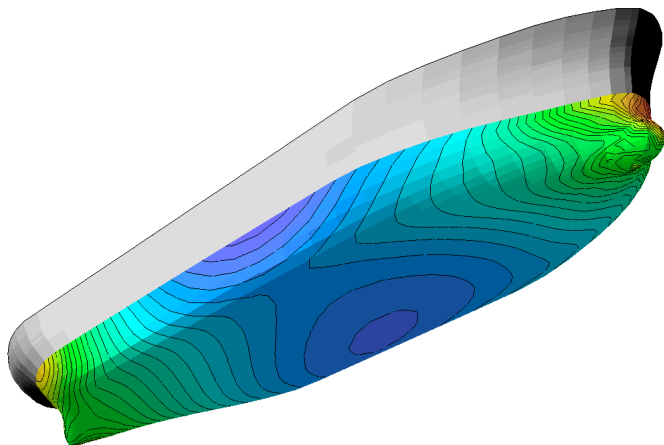
Scientific Marine Services (Escondido) has taken a lead role in feasibility studies, currently underway, aimed at using SPLASH pressure loadings in structural analyses, these being carried out by MCA Engineering (Costa Mesa).

Results so far show that detailed pressure loadings from SPLASH lead to more accurate stress predictions in structural members. Compared to on-board stress levels, SPLASH-based results are more realistic than those obtained using standard, less sophisticated, hydrodynamics inputs.

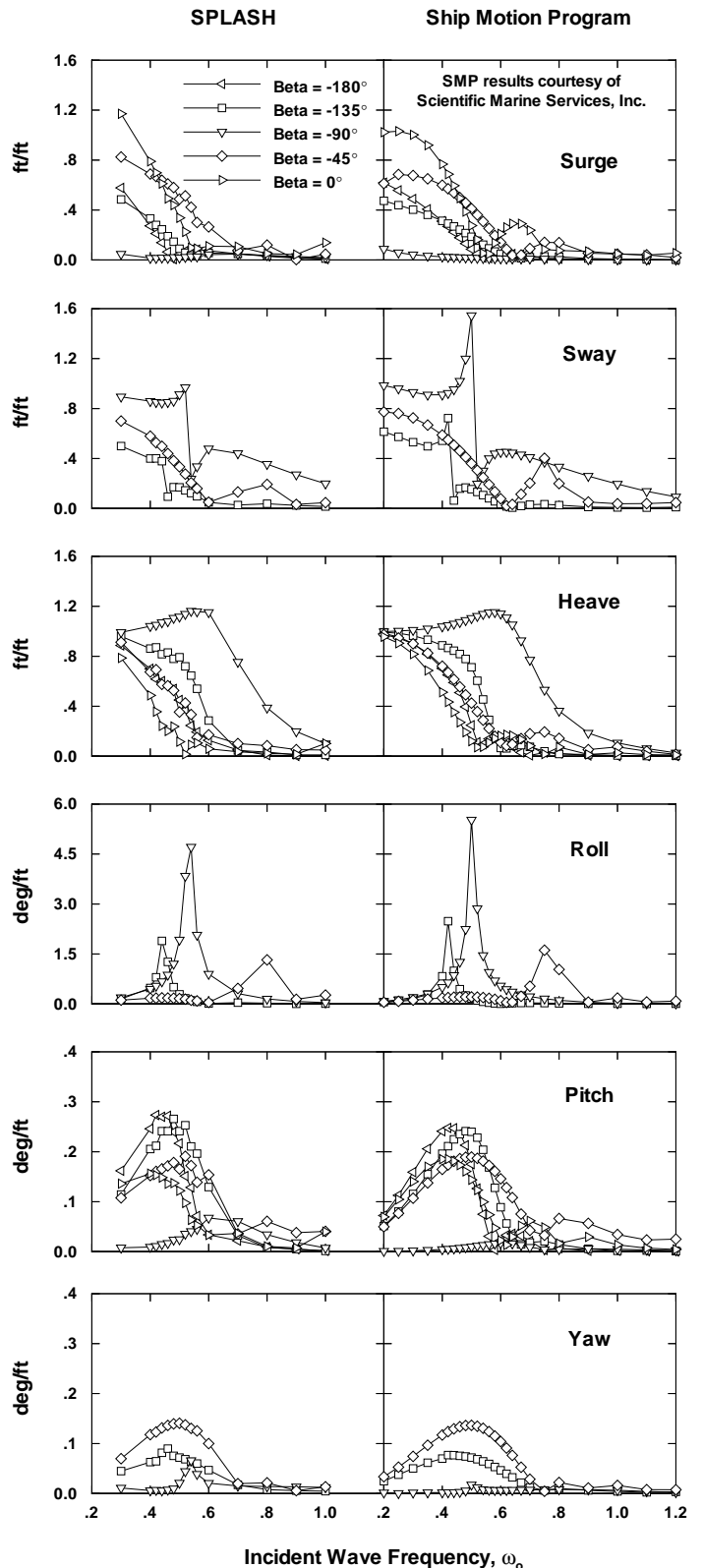
Instantaneous Snapshots of SPLASH Flow Fields



High Quality Unsteady Hull Pressure Input Data for Structural Analyses



SPLASH Unsteady Motions Comparison with SMP Code Predictions



Seakeeping: PACT/IACC Yacht Model Predictions

Use of nonlinear steady basis flow is critical to accuracy for yacht-type hull forms in waves

SPLASH steady flow predictions come in two flavors, linear and nonlinear. For yachts, which type you choose to base unsteady flow calculations on can make all the difference.

Free-surface effects introduce significant geometric and hydrodynamic nonlinearities, particularly at the Froude numbers typically of interest. Non-wall-sided hull forms with flare and overhang introduce additional nonlinearities. Capturing the nonlinear effects in the steady flow is critical to the accuracy of unsteady flow predictions.

In a classical linear steady flow solution, the wave flow is treated as a small perturbation to a simple basis flow ... the no-waves, double-body, flat free-surface flow. For flat free-surface panels, SPLASH returns these types of classical linear steady flow solutions.

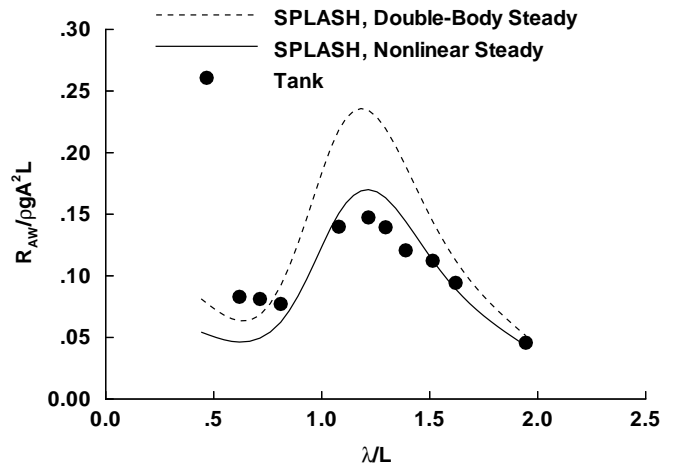
In a SPLASH nonlinear steady flow solution, panels are iteratively driven to their computed elevations. The basis flow is obtained first by treating all configuration and free-surface panels as solid and fixed. So as the panels converge to the computed elevations, the basis flow itself converges, to the nonlinear free-surface flow.

For SPLASH unsteady flows a similar approach is employed. Use a linear, flat free-surface panel model, and the unsteady flow is linearized about the steady double-body solution. Use a previously converged, nonlinear steady flow panel model, and the unsteady flow is linearized about the steady nonlinear solution.

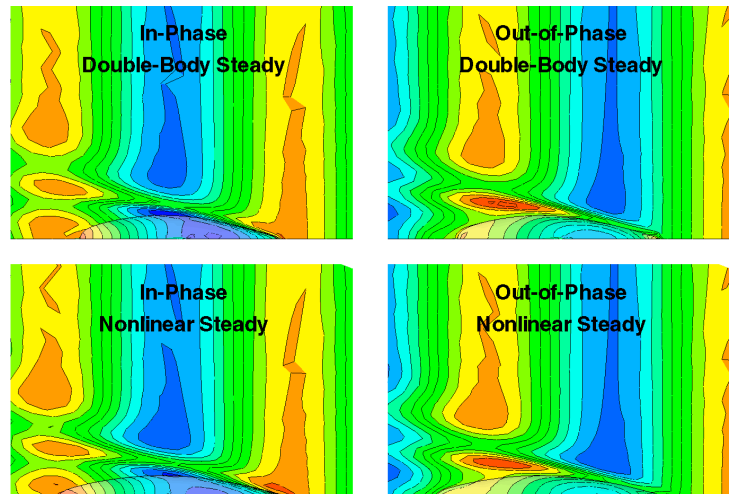
Only SPLASH offers high accuracy for both nonlinear steady and linearized unsteady flows, and the ability to combine these in a single, partially-nonlinear unsteady solution.

For IACC hulls the accuracy of SPLASH unsteady results, even using classical linear flat free-surface panel models, is unsurpassed. And using steady nonlinear free-surface panel models, accuracy of unsteady results is unprecedented.

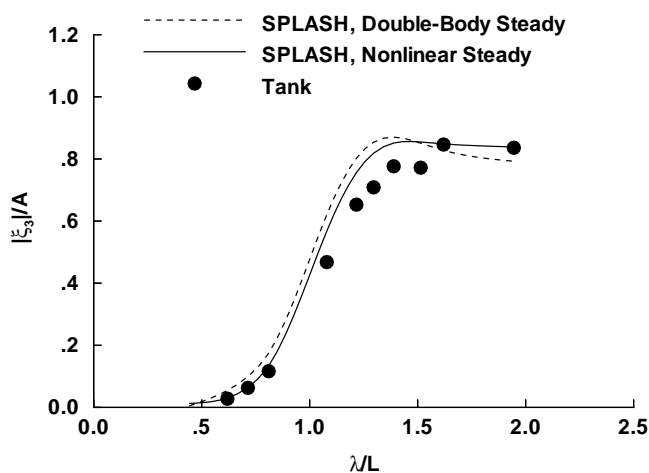
Added Resistance PACT Baseline Model



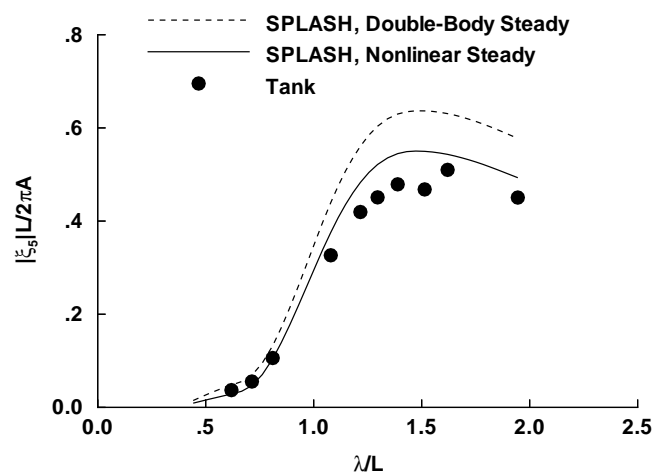
Unsteady Pressures



Heave Motions



Pitch Motions



Seakeeping: PACT/IACC Beam/Draft Model Series

SPLASH confirms effect of beam on performance in waves

For a generic IACC hull form, conventional wisdom says that added resistance in waves increases with beam, and SPLASH confirms this.

For the PACT beam/draft series, in which length and displacement are constant, ranking of added resistance in this fashion by a 3-D free-surface flow code is unprecedented.

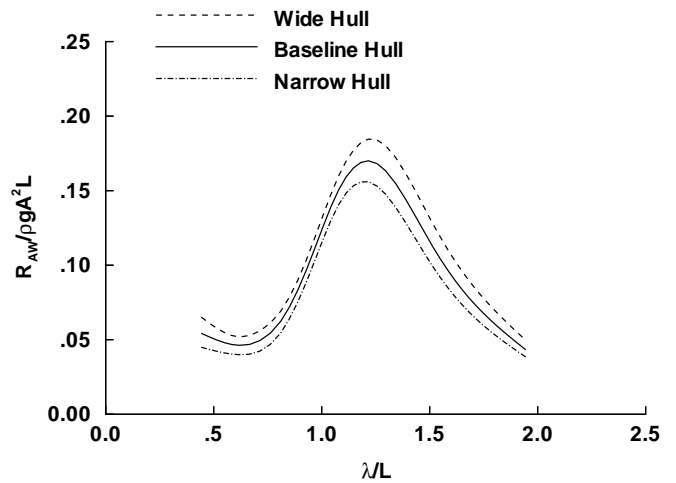
And SPLASH unsteady flow predictions show this same trend regardless of whether results are computed using a linear or nonlinear steady basis flow panel model. So the beam effect must be primarily "linear" in nature.

Too bad unsteady tank data for the PACT series isn't available for a boat-to-boat comparison. Of course, testing models in waves is difficult and expensive, and differences in added resistance may be no greater than uncertainty levels in tank data.

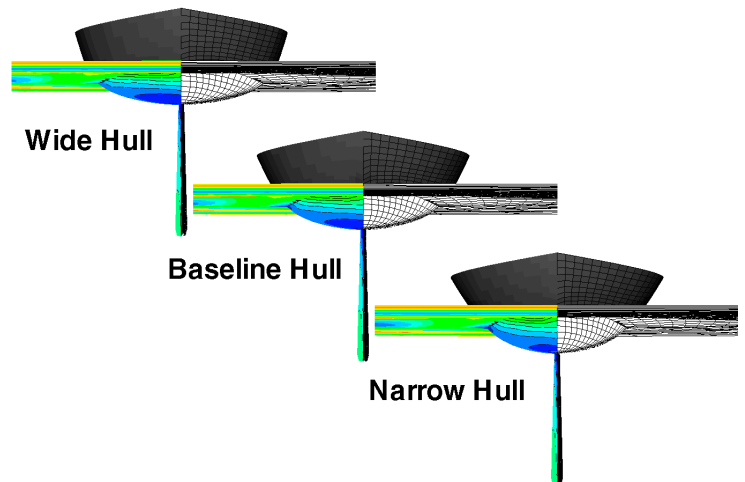
Compared to tank tests, SPLASH offers a cost effective and, in some cases, more reliable means of assessing yacht performance in waves. The strongest approach is to use SPLASH together with a limited test program. This minimizes costs and risks, while maximizing use of resources and, therefore, benefits for you.

Whether trying to optimize against mother nature or a rule such as the IMS VPP, your ideas for improving performance may involve a number of seakeeping issues and design tradeoffs. If so, rely on SPLASH, and be assured of the world's best flow simulations and numerical predictions for motions and added resistance in waves.

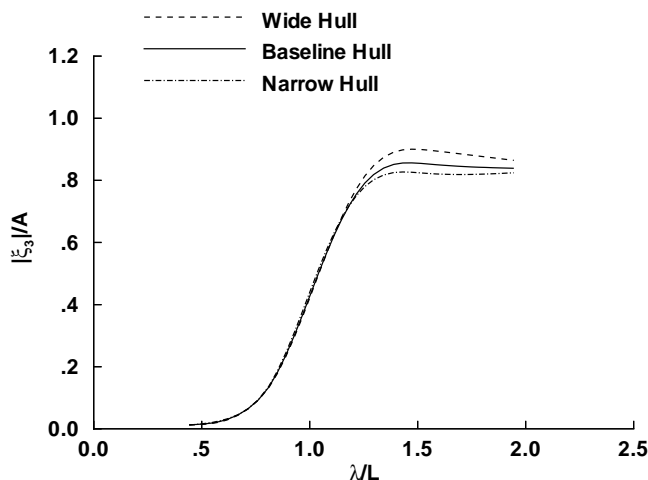
**SPLASH Added Resistance
PACT Beam/Draft Series**



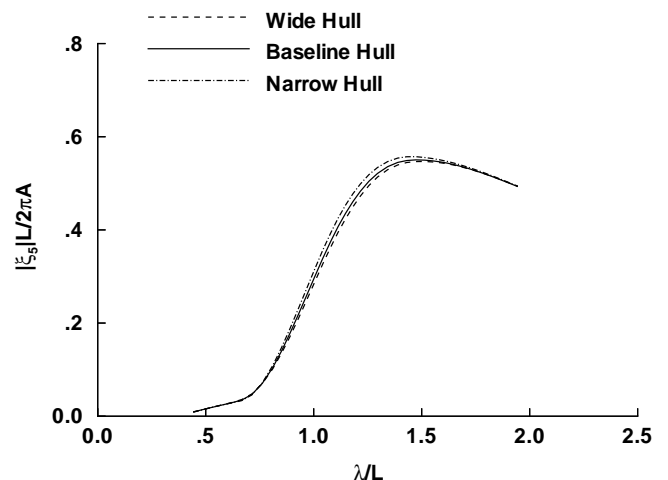
SPLASH Unsteady Pressures



SPLASH Heave Motions



SPLASH Pitch Motions



Seakeeping: Australian Entries, 1995 America's Cup

SPLASH added resistance predictions drive rough-water design of *oneAustralia-2*

Testing a complete IACC yacht model in waves is a difficult experiment. So designers of *oneAustralia-2* relied on SPLASH, in addition to the tank, for the added resistance predictions used in rough water VPP analyses.

Close to 100 hull forms were SPLASH'd in waves, and approximately 15 models were similarly tested in the tank. Overall, experimental and numerical predictions for added resistance were in good agreement. When differences did appear, SPLASH sometimes displayed the more reasonable behaviour, or was more in line with anticipated trends.

SPLASH added resistance predictions enabled rough water VPP analyses for a large number of models. Studies explored rough water implications of numerous design parameters:

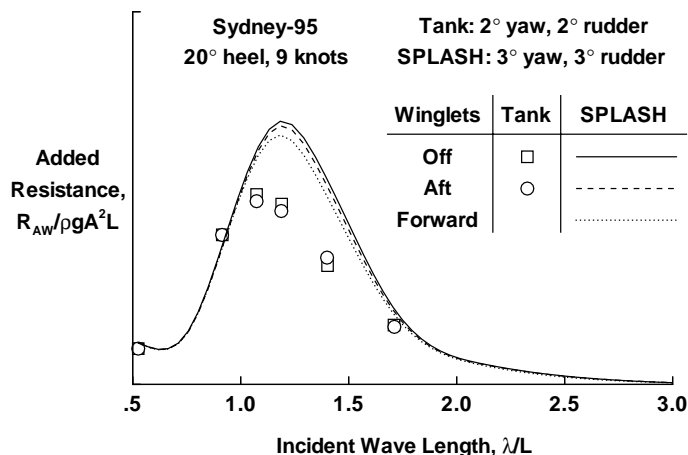
- length and displacement
- beam and draft
- prismatic coefficient
- location of center of buoyancy and center of flotation
- bow and stern shape, profile, overhang, girth penalties
- midship section shape, flair
- surface curvature effects
- keel/bulb/wing/rudder appendage contributions

SPLASH's 3-D flow simulation capabilities can provide added resistance predictions over a range of sailing conditions that are extremely difficult to study in most tanks:

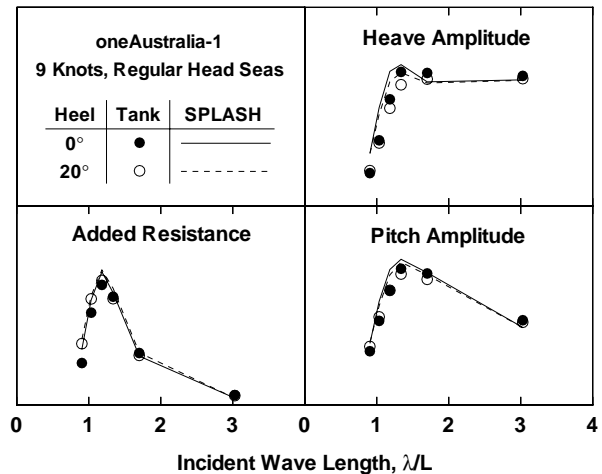
- heel and yaw
- incident wave heading angle
 - head seas
 - oblique, beam, and rear quartering seas
 - following seas

South Bay Simulations is the world leader in rough water performance predictions for yachts, and is committed to involvement in basic seakeeping research and development. Use SPLASH for rough water VPP's, and other unsteady flow studies, and benefit from this newly emerging technology.

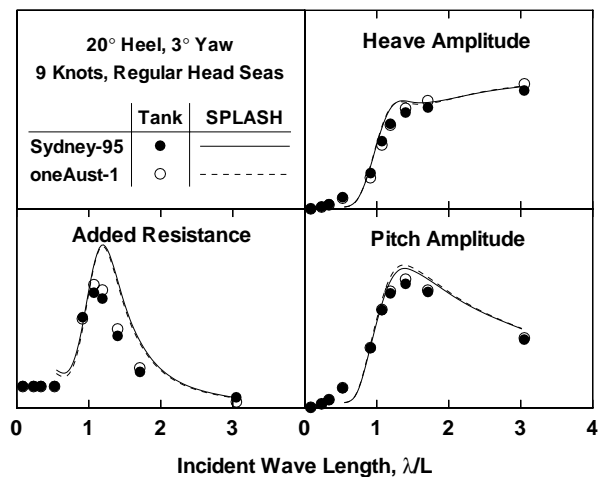
Winglet Added Resistance at Heel and Yaw



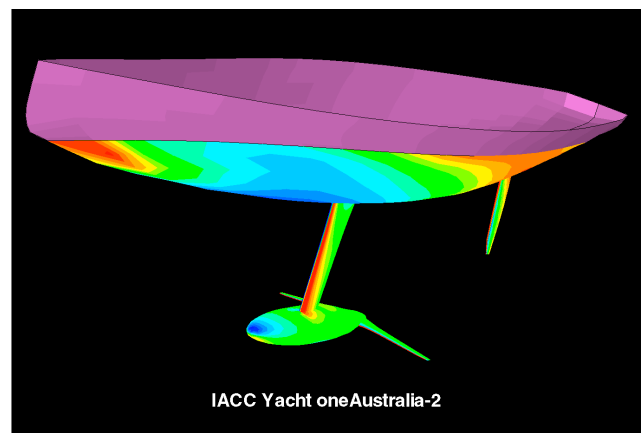
Motions and Added Resistance, Upright and Heeled

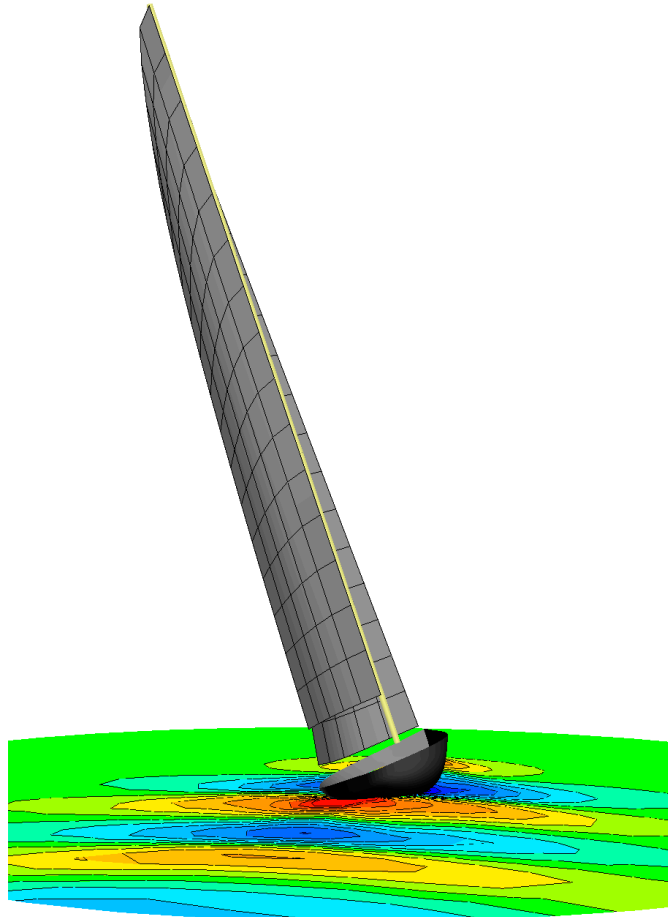


Motions and Added Resistance at Heel and Yaw



Unsteady Pressures at Heel and Yaw





SPLASH

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