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Ownship Modelling General Description

Kongsberg has a library of over 250 ship models of virtually every vessel type ranging from 7-metre rigid inflatable to VLCCs and Post Panamax ships. Every model has complete model documentation, which stipulates the particulars of the vessel and show the results achieved by the model when conducting all of the standard IMO manoeuvres.

The Kongsberg Maritime model keeper is based on modern technology using accumulated knowledge. It is the result of joint efforts of hydrodynamicists and researchers in St. Petersburg, Russia, Trondheim, Norway, Hamburg, Germany and our own staff of research and developers here at Kongsberg Maritime. Hydrodynamic models incorporated into the Kongsberg model keeper are based on accepted scientific principles, including traditional experimental hydrodynamics, hydrostatics, mechanics, control theory, etc.

The Kongsberg model keeper focuses on the physical approach for modelling ship, its elements and environment around it. Numerical algorithms used in the model keeper include solution of differential equations, spline interpolation, PID controllers, solution of systems of equations with multiple unknowns, etc. Various pieces of mechanical equipment (engine, auxiliary devices) on ship are simulated according to accepted engineering models. The model incorporates main engine and steering gear forces and effects such as: hull hydrodynamics, propeller(s) (fixed/variable pitch/ cycloidal propulsion), rudders and thrusters (bow/stern). External forces, such as fenders and dolphins, anchors & mooring lines, tugboats, ship interaction, grounding and collision, are also modelled. All external and internal forces and phenomena are completely synchronised to produce highly accurate, real time calculations of the ships' position in all six degrees of motion to a resolution of one (1) metre (or better); ships course calculations a resolution of better than 0.1 degree, and ships speed calculations at a resolution of better than 0.1 knot. The motion of the ship model is induced in all six degrees and will be a function of all internal and external stimuli to include sea state, wind conditions, and squat created by vertical and or horizontal water flow constriction. This motion is also fully synchronised with the visual scene and the associated motion of the waves.

The Kongsberg ship model includes comprehensive modelling of the ships engines, generators and steering arrangements. Torque load, and changes in shaft speed (i.e. change in nominal shaft RPM with change in pitch) and completely modelled. Also faults can be induced to include engine slow down, shut down, overload, over speed, lost of start pressure air, and propeller pitch control failures.

The various rudder forces are modelled independently to allow for the full range of conditions/ type of turning moment induced, for example ship with zero ground speed, rudder hard over, and engine ordered ahead, or ship speed 10 knots, rudder hard over, and engine astern. This applies to all rudder types as spade, flap (becker), schilling, bow rudders, flanking rudders, as well as combined steering and propulsion devices such as Z-Drive units, Azipods, and water-jets. The Kongsberg model server has been used to produce a variety of models with multiple propulsion units such as triple engine/shaft pusher tugs, nuclear aircraft carriers with four shaft lines, and multi-pod cruise ships with combined fixed and rotating azipods (i.e. Queen Mary 2).

Thruster units are modelled as an integral part of the ship hydrodynamic model and are one of the many components contributing to overall vessel motion. Engine start times, unit raising or lowering times (retractable thrusters), shaft reversing times, and nominal power are all developed to replicate those of the actual vessel type. As with a real ship, the turning moment or motion generated by the thrusters is a function of existing ship’s inertia and/or rotation about the longitudinal and lateral axis, the thrusters’ angle/ power settings, and any other external forces that influence the overall motion equation.

The Polaris simulator uses a variety of fender types to produce realistic responses when contacting another ship, a tug, a lock door, or berthing quay. Each of these fender types has unique properties for elasticity and viscosity. The diameter, length, and height of each fender can be set as appropriate for any dock area. The maximum number of fenders per database area is 1000.

Each ownship model has hawser or mooring line attach points and winches as would be representative of the vessel type. The vessel's attach points are described about the vessel's X, Y, and Z-Axis and any force applied to the lines act on the 3-diminsional 6-DOF model in a realistic fashion dependant upon the line's attach point, horizontal and vertical angle, the force that is applied, and any vessel motion. The speed of the winches, line weight, length and breaking strength are also modelled in a realistic way. The mooring line function supports all aspects of high fidelity shiphandling, berthing and mooring operations.

Any number of anchors can be modelled into an ownship including bow stern or keel anchors, their weight, chain length and hawse pipe position. As with hawsers, the resultant effect they have on vessel's motion is a function of the anchor chain's vertical and horizontal angle, ship's speed, and bottom type.

Modelling of “Wet Surface” Related Hydrodynamic Effects

The Polaris simulator models the entire underwater profile (wet surface) of the ship, as well as a fully contoured seabed. All aspects of this 3-dimensional model are incorporated in the computation of under bottom, and lateral side clearance, as well as all hydrodynamic effects. In the case of sinkage and squat, physical constriction in either the horizontal or vertical axis along any point of the hull form will effect, trim, squat and total sinkage. As in real life, speed through the water also has a significant impact on the overall resultant. This implies that these values will change considerably dependant upon whether or not the bottom is of homogenous depth, and or the channel is of homogenous width along the entire underwater form. Current and tidal stream forces, act on the whole wetted surface rather than on one point. Sheer, rotation, Coriolis effect etc. is produced accordingly. Current is considered as distributed in the vertical direction (layered) and is composed of current itself, wave-induced current and current due to piston effect in lock or narrow canal. The net result is highly realistic sheer, rotation, and drift as the ship transitions from one area of tidal, or water flow influence to another.

When the ownship meets another vessel (another ownship or a target vessel) the magnitude of the hydrodynamic interaction will be calculated based on channel width and depth, distance between ships, approach angle, the amount of hull overlap, the period of interaction, and both vessels speeds. These forces are on the whole wetted surface of the ownship to produce very realistic pressure and suction effects and the corresponding sheer, rotation, and speed loss.

The Polaris simulator models bank effect taking into account the length and slope of the bank, the ownship speed, and angle of convergence/ divergence. As with squat affect, the degree of channel constriction in both the horizontal and vertical axis, and the ability of water to flow around the ship as a direct effect on the magnitude of bank effect.

The fidelity of the ship’s response to current in the Polaris simulator is also a function of the database area current modelling capabilities. Polaris has both a simplex manual mode of entering linear, non-dynamic current values and a comprehensive “current chart” mode, which automatically calculates and applies dynamic current values. The chart mode allows the instructor to create variations in the height of tide throughout a database area. It will also allow for the modelling of complex horizontal water flow in order to create conditions with a variety of tidal stream or current directions and velocities to include effects such as tidal races, back eddies, lee effects in sheltered areas, and sheer as a vessel transits through an area with varied current effects. When running an exercise and using tidal chart mode the simulator can synchronise the horizontal and vertical water flow and their associated values change automatically over the course of the exercise run-time. In order to simulate these conditions to an acceptable degree of fidelity the following are the minimum capabilities of this system:

- ability to process information from at least 5000 integrated tidal diamonds simultaneously. Each tidal diamond has the capability to be edited by the instructor and to contain data for both vertical and horizontal movement of water over a full 12 hour tidal cycle;
- ability to adjust or smooth the output value from the above mentioned tidal diamonds to allow for the normal variations in the lunar cycle such as spring and neap tide as well as diurnal inequalities;
- ability to have up to 10 secondary ports that any tidal diamond can be associated with in order to effectively simulate at any number of geographic locations, the natural variations in timings and amplitude of conditions/ phenomena such as high water, low water, turn to ebb, turn to flood, etc.;
- ability for each tidal diamond to contain unique direction and velocity values at least 10 different depths or layers;
- ability to control the duration and directional effects during the transitional period that occurs around slack water to reflect normal tidal patterns experience in both open water, and in contrast, in rivers or canals where a 180 degree shift in horizontal water flow can occur in a matter of minutes; and
- ability to create tidal vector maps that replicate the information that is portrayed in North American style tidal atlases for a given state of tidal stream, for example two hours after high water. The direction and velocity of these vectors need not change with time, but can allow the instructor to create shiphandling problems that deal with a very specific tidal stream condition. As with the tidal diamonds, the simulator capable of processing at least 5000 tidal

vectors simultaneously. Each tidal vector has the capability to be edited by the instructor and to contain unique data for up to 10 different depths or layers.

- Ability to create offline complex tidal stream and current files that can be either static or dynamic with time steps as discrete as 1 minute increments and in any type of cycle pattern to allow for simulation of phenomena such as semi-diurnal tides, river estuaries, and lock outflow currents. These files are in ASCII format and lend themselves well to the importation/ conversion of third party waterflow prediction models.

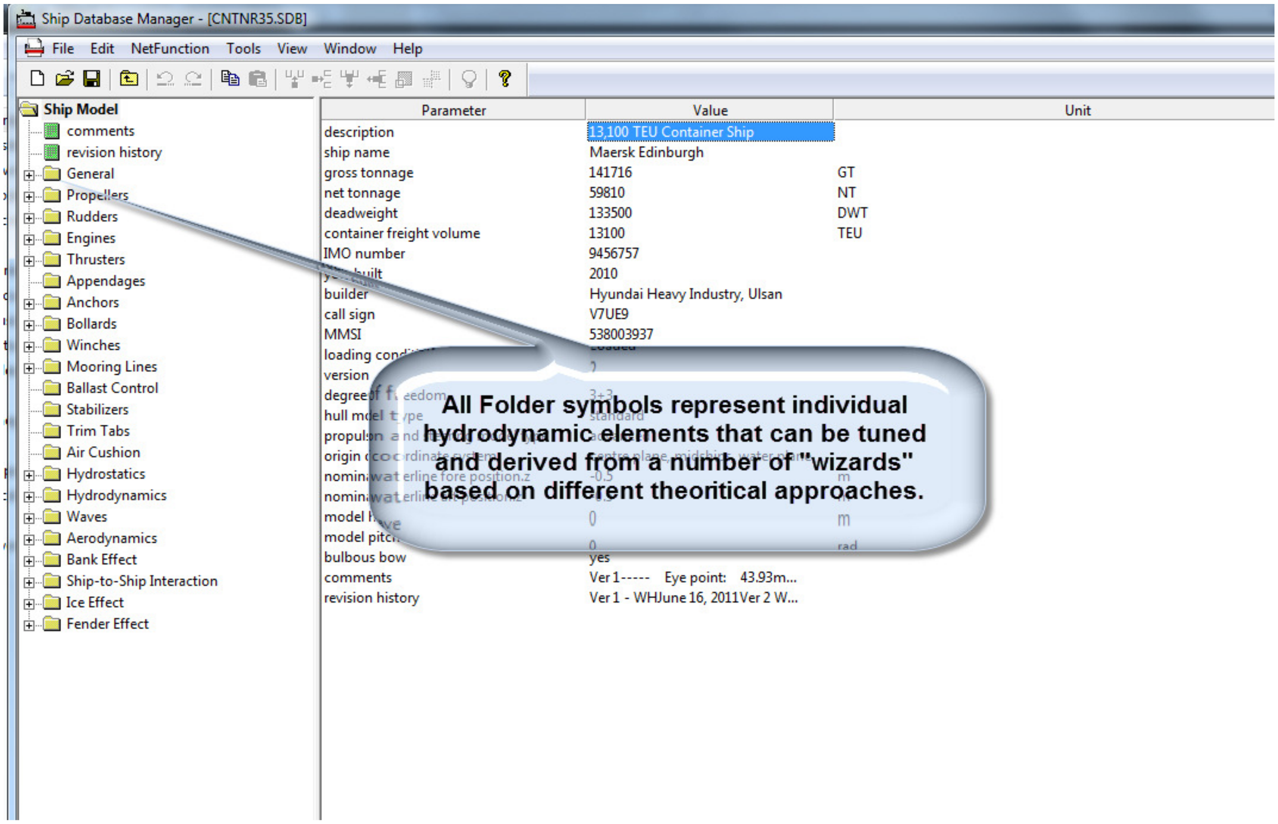
Modelling of "Dry Surface" and Other Related Hydrodynamic Effects

The Polaris simulator models the entire freeboard profile (dry surface) of the ship, the wind acts on the whole dry surface rather than on one point. Sheer, rotation, drift effect etc. is produced accordingly. Wind gusts directly impact on the magnitude of these effects. The net result is highly realistic sheer, rotation, and drift as the ship transitions from one area of wind influence to another. As with current, the Polaris wind model supports the use of either manual linear values, or comprehensive wind maps. The wind maps support the creation of wind effects that factor in physical and geographic effects so that the resultant wind speed and direction vary automatically as a ship transits from a sheltered area to a lee area.

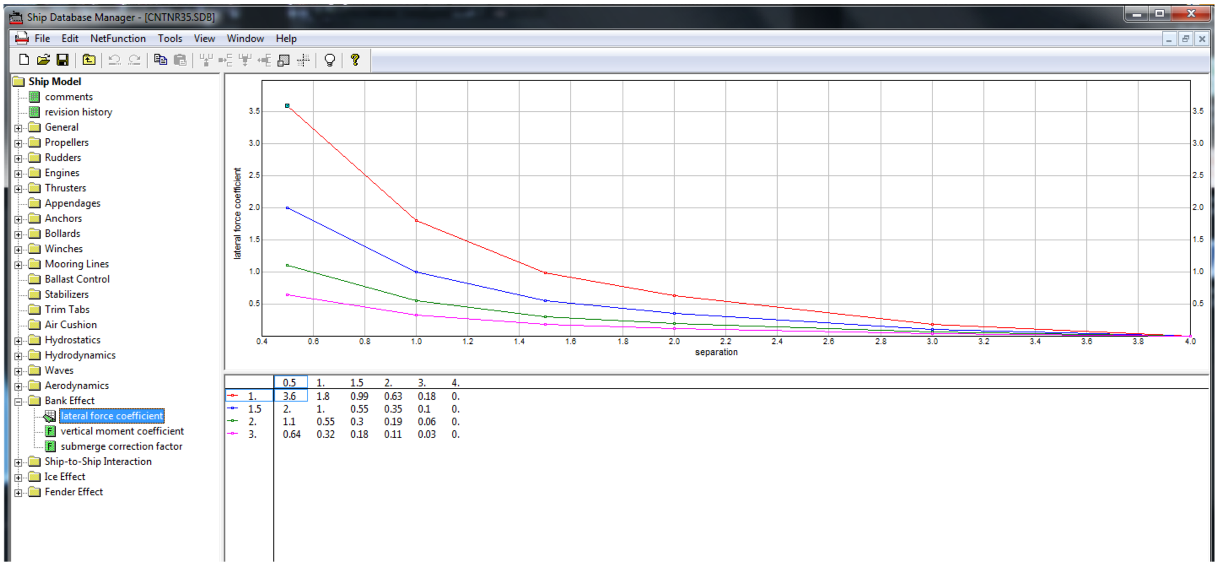
Wind driven waves and swell (both in direction, height, and wave length) are modelled independently of one another in Polaris in order to permit the creation of a full range of Sea States. In the case of swell, the maximum wave period is 14 seconds and the maximum wavelength is 1024 metres. The three dimensional model of the ship is fully synchronised to wave motion and the resultant motion in six-degrees of freedom will be a function of combined sea state, vessel speed, any turn or acceleration rate, and wave angle of attack.

Large ships (both ownships and targets) produce wind and wave lee effects for smaller vessels in their vicinity (i.e. RHIB, Pilot Boat, tugs, etc.).

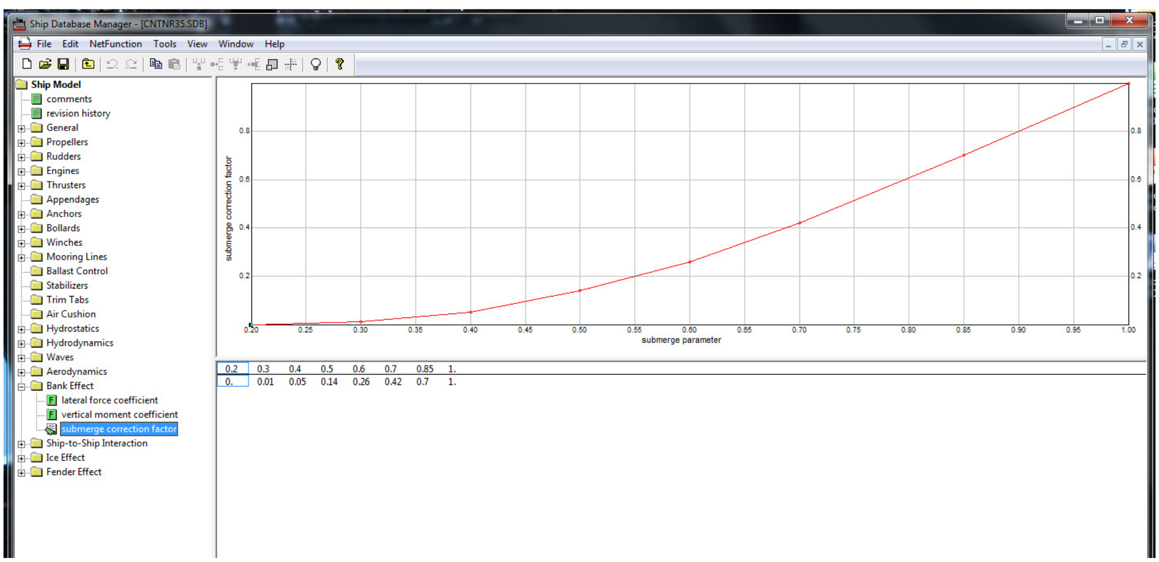
Illustrations from Hydrodynamic modelling Tool (HDMT).



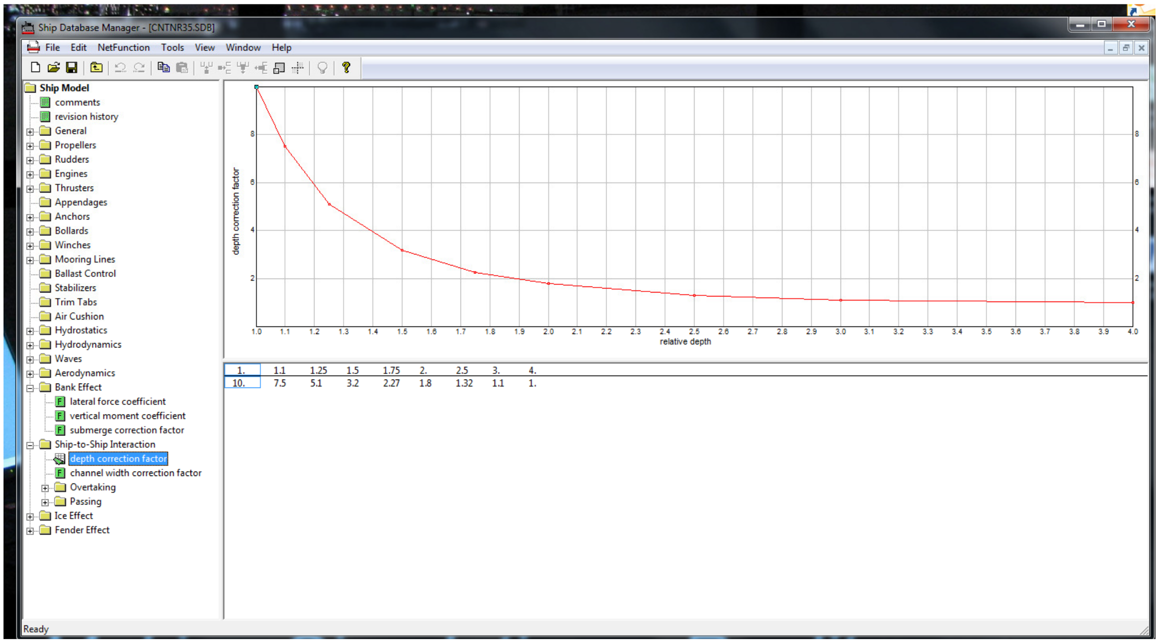
Bank Effect: Lateral Force Coefficient computation based on distance from bank.



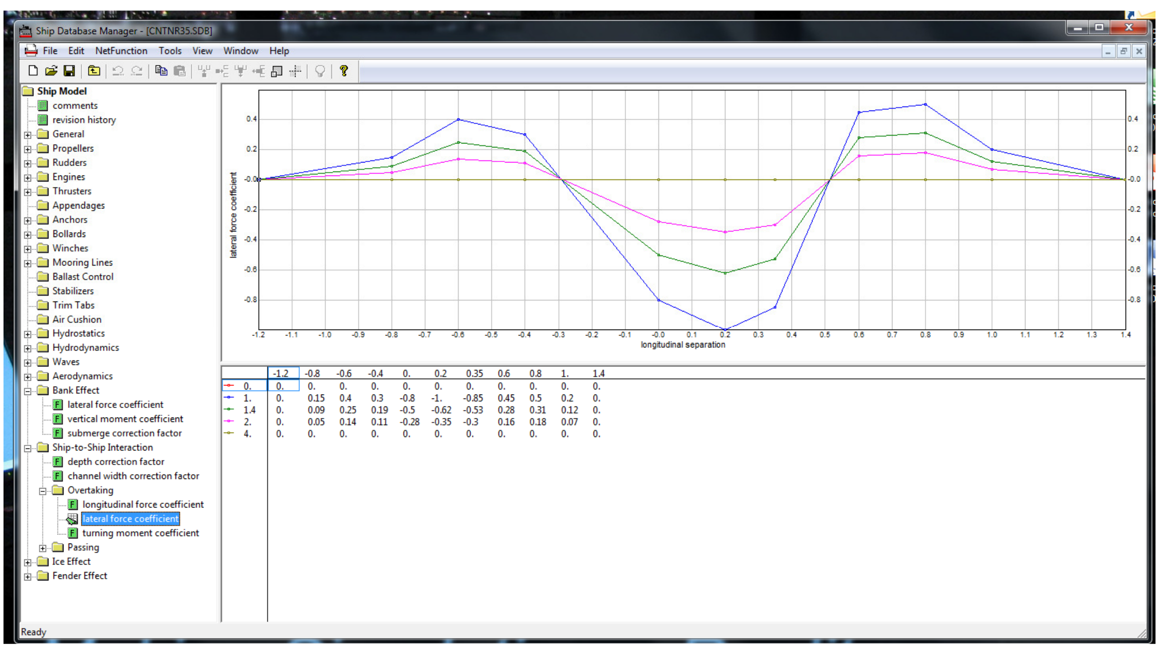
Bank Effect: Lateral Force Coefficient computation for submerged bank.



Ship to Ship Interaction: Depth factor computation



Overtaking Ship: Lateral Force Computation for lateral separation between vessels.



Tugging

The Polaris simulator supports two distinct types of tug-assistance, target tugging, and ownship tugging.

The “Target Tugging” ship assist mode uses a combination of automated and manual control modes, which allow the instructor to position/ re-position and connect/ re-connect the tug (either bow or stern in) at the various attach points that are programmed into the ship model. Using these same control tools, the instructor can apply to an ownship a full range of tug forces. A maximum of eight target tugs can be used simultaneously. The direction and magnitude of these forces can be completely controlled by the instructor to ensure that generated line tensions or frictional push forces are correct and realistic for the type of tug (conventional, tractor etc.), the mode of operation (push, direct pull, indirect, and powered indirect pull), and the actual speed/ motion of the big ship that is being assisted/ escorted. The tug’s angle to the ship, line connection and line catenary/ tension are accurately depicted in the visual scene based upon the orders applied to the tug by the instructor.

Ownship tugging incorporates all of the sophistication of other models described in the previous sections when assigned to a student bridge. When a tug is connected to another ownship, the tug will produce a full range of external forces (friction, drag, line tension, sheer etc.) associated with actual tugging operations. As with other models, the magnitude of these forces is fully synchronised with all environmental and situational elements such as sea state, tug speed, big ship or towed vessel speed, etc.

There are more than 15 different ownship tug models spanning all vessel types from ship assist tugs, to towboats to pusher tugs. Examples of all types of standard tug propulsion (single screw, twin screw, Voith-Schneider, and Z-Drive), as well as variety of skeg and hull types have been modelled. Correspondingly, a full range of vessel control options exist in order to populate the bridge with the appropriate control systems for the different types of vessels.

The latest generation of tug models are equipped with highly detailed fendering arrangements to support realistic friction and to “stick to” a moving ship when pushing without a line attached. These models also have detailed small vessel to big vessel hydrodynamics to create realistic interactions when working a moving big ship around the bow, beam and stern. Winch particulars are accurately modelled, and there are a variety of available line types. The under water profile and skeg of the tugs are also modelled to ensure the tug can produce very realistic line forces and handling characteristics when working in the indirect and powered indirect modes for ship escort operations. Kongsberg tugs are also well suited to towing operations and can tow a barge from astern or can be made up to the barge on the hip, or can push the barge from astern. The combination of these capabilities, make these tug models highly suitable for training tug captains, pilots, and for interactive training scenarios (pilots and tug captains combined) to support proof of concept and or port policy/ port development studies. Additionally, the capability of these tugs can be exploited from the instructor control position using virtual ownships, which reside on the instructor's PC. This implies that pilots can be manoeuvring large ownships in each full mission bridge and can work with full fidelity tug models which are controlled by the instructor at the control station, (rather than a tug captain in another full mission bridge). This provides an exceptionally high degree of flexibility when conducting pilot training. Corresponding, the reverse can be done when conducting tug captain training by running the large ownship or barge from the instructor position, and using all full mission bridges as tugs.

The Kongsberg model keeper and its Polaris implementation have been used in a number of research projects. Kongsberg's "Named" ship models have been specifically developed to mirror actual vessels physical characteristics and layout, and their recorded sea trial data.